Tongue pressure is associated with aging, sex, handgrip strength, and lean body mass in community-dwelling middle- and old-aged people: a cross sectional study

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The relationship between tongue pressure and relevant factors including cardiovascular disease (CVD)-related factors in community-dwelling middle- and old-aged people is still controversial. To clarify the relationship between tongue pressure and relevant factors including CVD-related factors in community-dwelling middle- and old-aged people. We included 638 Japanese community-dwelling adults (241 men and 397 women) who participated in the screening program and agreed to participate in this study. We measured the tongue pressure using a JMS tongue pressure measuring instrument® with a disposal oral balloon probe, and we conducted multivariate linear regression analysis to evaluate the relationship between tongue pressure and other existing parameters adjusted for CVD-related confounding factors. We showed that tongue pressure was significantly correlated with age ($\beta = -0.114$), sex ($\beta = 6.374$, Men=2, Women=1), lean body mass ($\beta = 0.278$), and log grip strength ($\beta = 22.438$). Our study showed that these parameters were all independent explanatory valuables for tongue pressure in community-dwelling middle- and old-aged people. Age, sex, grip strength, and lean body mass were all independent explanatory valuables for tongue pressure in community-dwelling middle- and old-aged people.

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Introduction

Swallowing is an important task of the human tongue, and a reduction in the tongue's muscle strength causes dysphagia[1-4]. Reduced tongue strength, in combination with other physiological causes of dysphagia, is one of the most life-threatening factors for aging societies.

A reduction in the tongue's muscle strength has shown the association with obstructive sleep apnea (OSA)[5-7]. OSA results in many complaints such as daytime sleepiness, nonrestorative sleep, and snoring and is associated with an increased risk of cardiovascular diseases (CVD)[8,9]. Furthermore, it is well known that OSA is associated with cardiovascular risk factors, CVD, and increased mortality[10]. The events

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associated with OSA lead to brain arousal, intrathoracic pressure changes, and intermittent episodes of hypoxemia and reoxygenation, and these events activate pathways such as oxidative stress, sympathetic activation, inflammation, hypercoagulability, endothelial dysfunction, and metabolic dysregulation that predispose patients with OSA to hypertension and atherosclerosis[11]. Therefore, the tongue muscle must be evaluated objectively to predict the risk of OSA as well as the swallowing function.

Recently, Butler et al. found that tongue status was positively associated with handgrip strength in healthy older adults[12], and Buehring et al. evaluated tongue strength in community-dwelling elderly people to determine the correlation between tongue strength and classic muscle function tests and showed that tongue pressure is positively correlated with grip strength and jump height and power[13]. Maeda et al. conducted a study to clarify the relationship between tongue pressure and sarcopenia related-factors in hospitalized elderly people using a novel method for the measuring tongue pressure with a balloon-type disposable oral probe[14] and found that sarcopenia, nutrition status, and age were independently associated with tongue pressure[15]. However, these studies did not evaluate the relationship between tongue pressure and CVD-related factors such as blood pressure, lipid profile, and carotid intima media thickness (CIMT).

In this study, we conducted a cross-sectional study to clarify the relationship between tongue pressure and relevant factors including CVD-related factors in community-dwelling middle- and old-aged people. Our hypothesis was that tongue pressure is associated with CVD-related factors as well as age and sex.

Subjects and Methods

Study Subjects

This study was approved by the ethical committee of Nagasaki University Graduate School of Biomedical Sciences (project registration number 0501120073). Written consent forms were available in Japanese to ensure comprehensive understanding of the study objectives, and informed consent was provided by the participants.

This study was conducted during a medical screening program for the general population living in Goto City, Nagasaki Prefecture, Japan, in 2015. Blood samples and medical information were collected by the staff of Nagasaki University in cooperation with the staff of Goto City. The study included 638 Japanese community-dwelling adults (241 men and 397 women) who participated in the screening program and agreed to participate in this study.

Data Collection

The height of each participant were measured, and the body mass index (BMI; kilograms per meter squared) was calculated as an index of obesity. Body weight and fat rate were also measured by body fat mearing instrument (InnerScan®, Tanita, Japan), and the lean body mass (LBM) was calculated as the following formula: LBM (kg) = ((1 − fat rate) × body weight (kg)). Handgrip strengths (GS) were measured by dynamometer (DX T-2288®, TOEI LIGHT, Japan) after cuing by staff using both hands in five seconds respectively, and their average was used for analysis. The systolic blood pressure (SBP) and diastolic blood pressure (DBP) were recorded at rest.

Maximum tongue pressure was measured using the JMS tongue pressure measuring instrument® (JMS, Hiroshima Japan) with a disposal oral balloon probe[15]. Since previous studies using same device used maximum tongue pressure for analysis, we also used maximum tongue pressure in this study[14,15]. The measurement details are described elsewhere[15]. Briefly, we measured the increase in air pressure in the balloon that is produced when the balloon at the tip part of the plastic pipe probe is pressed between the front part of the palate and the tongue. Before measurement, we explained the measurement methods to each study participant. They were placed in a sitting position, and the balloon was placed in their mouth. They held the plastic pipe at the midpoint of their central incisors with a closed lip and compressed a small balloon attached to the probe tip between the tongue and the anterior part of the hard palate for 5 seconds with maximum voluntary effort. Each measurement was repeated 3 times at 30-s intervals, and the maximum value was used for the analysis.

Blood samples were collected from each participant after fasting overnight. Serum was separated and stored at −20°C until assay. The serum concentrations of triglyceride (TG) were measured by enzyme methods, and high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) were measured by direct methods. Also, hemoglobin A_{1c} (HbA_{1c}) was measured by latex agglutination method, serum creatinine, and uric acid (UA) were also measured by enzyme methods.

CIMT was measured by ultrasonography of the right and left carotid arteries using a LOGIC Book XP with a 10-MHz linear array transducer (GE Medical Systems, Milwaukee, WI, USA). Subjects were examined in the supine position.

On a longitudinal two-dimensional ultrasonographic image of the carotid artery, the far wall of the carotid artery is displayed as two bright white lines separated by a hypoechoic space. The distance from the leading edge of the first bright line (lumen-intima interface) to the leading edge of the second bright line (media-adventitia interface) was identified as the CIMT. The images were analyzed using Intima Scope software (MEDIA CROSS, Tokyo, Japan). The average of the right and left CIMTs was calculated and used in the analysis.

Statistical Analysis

The results are expressed as mean ± standard deviation or median (25–75 quartiles). The differences in laboratory values between women and men were evaluated using the *t*-test and Mann-Whitney's U-test. Multivariate linear regression analysis was performed to evaluate the relationship between tongue pressure and other existing parameters adjusted for CVD-related confounding factors including sex (Men=2, Women=1). Because GS, UA, HDL-C, HbA_{1c}, and CIMT were skewedly distributed, a logarithmic transformation was performed for the univariate and multivariate linear regression analyses. Probability values less than 0.05 were considered statistically significant. All data were statistically analyzed using SPSS ver. 19.0 software (IBM Japan, Tokyo, Japan).

Results

Table 1 shows the characteristics of the study participants. The average age of men and women was 71.0 and 70.0 years and the maximum tongue pressure in men (n = 241) and women (n = 397) was 30.5 ± 10.6 and 28.3 ± 9.9 kPa, respectively (p = 0.01, Figure 1).

In both men and women, maximum tongue pressure declined with age (r = −0.443 in men and r = −0.311 in women, Figure 2). In men, maximum tongue pressure was positively correlated with LBM (r = 0.325), BMI (r = 0.222), log GS (r = 0.450), Hb (r = 0.141), and log UA (r = 0.058) and negatively correlated with log CIMT (r = −0.128) by univariate linear

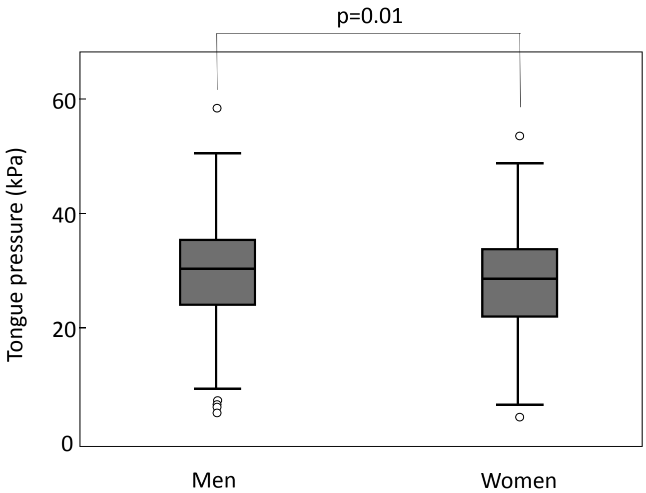

Figure 1: Differences of tongue pressures in men and women.

Table 1. Characteristics of the study participants

	Men (n = 241)	Women (n = 397)	
Age (years)	71.0 (64.0 - 78.0)	70.0 (62.0 - 77.0)	70.5 (63.8 - 78.0)
tongue pressure (kPa)	30.5 ± 10.6	28.3 ± 9.9**	29.1 ± 10.2
BFP (%)	23.3 ± 5.1	33.3 ± 6.2**	29.5 ± 7.6
LBM (kg)	48.6 ± 6.1	34.6 ± 3.8**	39.9 ± 8.3
BMI (kg/m^2)	23.8 (21.9 - 25.9)	23.2 (20.9 - 25.5)*	23.5 (21.2 - 25.7)
SBP (mmHg)	137.3 ± 18.4	137.1 ± 17.8	137.2 ± 18.1
GS (kg)	31.4 (25.8 - 36.9)	20.5 (16.1 - 23.9)**	23.1 (18.6 - 29.0)
Hb (g/dl)	14.4 ± 1.3	13.0 ± 1.2**	13.5 ± 1.4
Ht (%)	43.4 ± 3.7	40.0 ± 3.3**	41.3 ± 3.8
UA (g/l)	0.058 (0.051 - 0.066)	0.048 (0.041 - 0.056)**	0.052 (0.044 - 0.061)
TG (g/l)	0.81 (0.62 - 1.2)	0.91 (0.65 - 1.3)	0.89 (0.64 - 1.3)
HDL-C (g/l)	0.52 (0.44 - 0.62)	0.59 (0.50 - 0.70)**	0.57 (0.47 - 0.67)
LDL-C (g/l)	1.1 ± 0.29	1.2 ± 0.29**	1.2 ± 0.29
HbA_{1C} (%)	5.6 (5.4 - 5.9)	5.6 (5.4 - 5.9)	5.6 (5.4 - 5.9)
CIMT (mm)	0.75 (0.65 - 0.86)	0.69 (0.60 - 0.78)**	0.71 (0.61 - 0.80)

Values are mean ± standard deviation. *p<0.05 and **p<0.01 vs men.

BFP, body fat percentage; LBM, lean body mass; BMI, body mass index; SBP, systolic blood pressure; GS, grip strength; Hb, hemoglobin; Ht, hematocrit; UA, uric acid; TG, triglyceride; HDL-C, high-density lipoprotein-cholesterol; LDL-C, low-density lipoprotein-cholesterol; HbA_{1c}, hemoglobin A_{1c}; CIMT, carotid intima media-thickness.

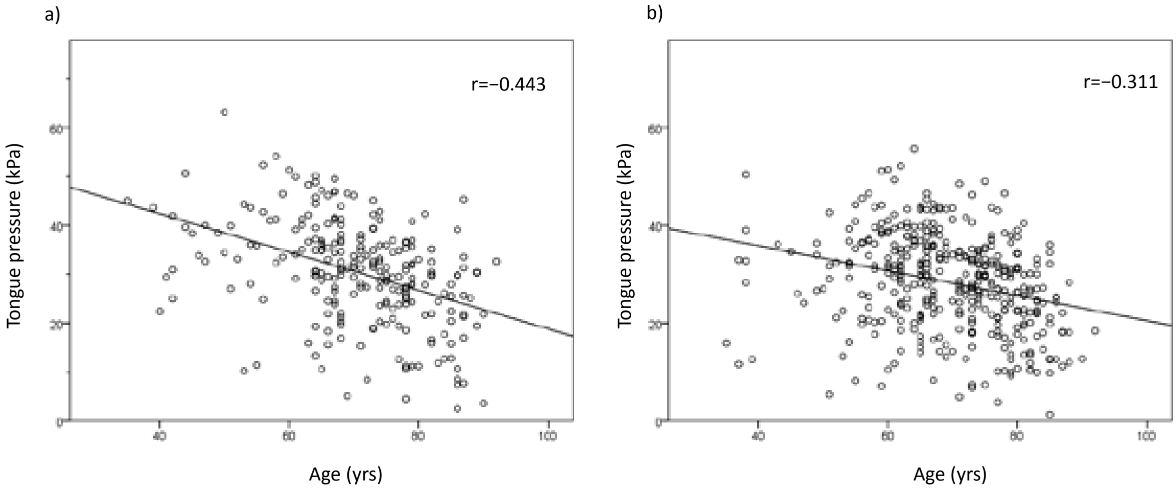

Figure 2: Relationship between age and tongue pressure in men (left) and women (right).

regression analysis. In women, it was positively correlated with LBM (r = 0.257), BMI (r = 0.116), log GS (r = 0.395), Hb (r = 0.207), and LDL-C (r = 0.110) and negatively correlated with CIMT (r = −0.218). In all subjects, it was positively correlated with LBM (r = 0.247), BMI (r = 0.165), log GS (r = 0.394), Hb (r = 0.205), and log UA (r = 0.105) and negatively correlated with log CIMT (r = −0.150).

In multivariate linear regression analysis adjusted for age and sex, maximum tongue pressure was significantly correlated with LBM (β = 0.405), BMI (β = 0.474), log GS (β = 25.183), and Hb (β = 0.702). Furthermore, in multivariate linear regression analysis adjusted by CVD-related confounding factors, maximum tongue pressure was significantly correlated with age (β = −0.114), sex (β = 6.374, Men = 2, Women = 1), LBM (β = 0.278), and log GS (β = 22.438) (Table 2).

Table 2. Multivariate linear regression analysis of tongue pressure adjusted for a) age and sex (Men=2, Women=1) and b) CVD-related factors.

a)

Variables	β	95% CI	p value
LBM	0.405	0.240, 0.570	<0.001
BMI	0.474	0.258, 0.690	<0.001
log GS	25.183	18.917, 31.449	<0.001
Hb	0.702	0.069, 1.334	0.030
log HDL-C	4.274	−2.597, 11.144	0.222
log CIMT	1.138	−10.012, 12.289	0.841

b)

Variables	β	95% CI	p value
age	−0.114	−0.194, −0.034	0.005
sex	6.374	3.527, 9.221	<0.001
LBM	0.278	0.115, 0.441	0.001
log GS	22.438	16.012, 28.864	<0.001
Hb	0.279	−0.330, 0.888	0.369

β: regression coefficient. CI, confidence interval. Other abbreviations as in Table 1.

Discussion

In this cross-sectional study with a relatively large number of community-dwelling middle- and old-aged people, we found that maximum tongue pressure is stronger in men than in women. We also showed that age, sex, grip strength, and lean body mass were all independent explanatory valuables for tongue pressure. On the other hand, we found that maximum tongue pressure was not independently associated with CVD-related factors such as blood pressure, lipids, HbA_{1c}, and CIMT.

In our study, maximum tongue pressure was stronger in men than in women, and sex was the independent explanatory valuable for maximum tongue pressure. We also showed that maximum tongue pressure declines with aging in both men and women. Previously, Utanohara et al. evaluated the standard values for the maximum tongue pressure of Japanese healthy adults and showed that tongue strength declined with natural aging, which is consistent with our results[15].

We showed that grip strength was independently associated with maximum tongue pressure. This result shows that muscle strength is an important determinant of tongue pressure. Consistent with our results, previous studies showed that tongue strength is positively associated with grip strength, which suggests that skeletal muscle loss (sarcopenia) affects not only the muscle strength of the extremities but also the tongue strength[12,13]. Currently, sarcopenia in the elderly has become an important health issue in aging society because it becomes a risk factor for various diseases. It is well known that sarcopenia is associated with falls, frailty, fractures, and mortality[14,17]. Furthermore, dysphagia due to sarcopenia in the elderly becomes an important health issue because it is an important risk factor of aspiration pneumonia[18]. We also showed that lean body mass was the independent explanatory variable for tongue pressure. This shows that muscle mass itself as well as muscle strength are determinants of tongue pressure. Our results reconfirmed the importance of health promotion in the elderly through improved physical activities.

On the other hand, we showed that CVD-related factors such as blood pressure, lipids, HbA_{1c}, and CIMT were not independently associated with maximum tongue pressure. Kanezaki et al. showed that tongue strength was negatively associated with obstructive apnea time and apnea index, and they concluded that the tongue strength is predictive of the airway patency during sleep in OSA[19]. Furthermore, it is well known that OSA is associated with cardiovascular risk factors, CVD, and increased mortality[20]. Based on such evidence, we evaluated the relationship between tongue pressure and CVD-related factors such as blood pressure, lipids, HbA_{1c}, and CIMT; however, we did not find a significant relationship between them. On the other hand, it has been clarified that oral health status, especially periodontitis, is associated with CVD[21]. Therefore, continuous attention should be paid to oral health, including the tongue status, and CVD risk.

This study has several limitations. We could not evaluate the oral status including the status of teeth and periodontitis, OSA status, current status of dysphagia and detail health status in study participants. It has been clarified that the tongue may compensate for the missing teeth in the masticatory performance of those elderly who have lost their natural teeth[22]. Also, our results might not be generalized since current study participants are Japanese only. We could not consider some information about the study participants, such as smoking status and intake of drugs such as antihypertensive drug and statins, that affect the status of CVD-related factors. The lack of this information might cause a bias in the results during statistical analysis. Further evaluation, such as longitudinal approach is needed to clarify the factors associated with tongue pressure, especially CVD-related markers.

In conclusion, age, sex, grip strength, and lean body mass were all independent explanatory valuables for maximum tongue pressure in community-dwelling middle- and old-aged people. On the other hand, maximum tongue pressure was not independently associated with CVD-related markers such as blood pressure, lipids, HbA_{1c}, and CIMT. Further studies are needed to identify the factors related with tongue strength to outline policies for improving the oral health status of the general population.

References

1) Ulrich Sommer J, Birk R, Hörmann K, Stuck BA. Evaluation of the maximum isometric tongue force of healthy volunteers. Eur Arch Otorhinolaryngol 271:3077-3084, 2014.
2) Cabre M, Serra-Prat M, Palomera E et al. Prevalence and prognostic implications of dysphagia in elderly patients with pneumonia. Age Ageing 39-45, 2010.
3) Hudson HM, Daubert CR, Mills RH. The interdependency of protein-energy malnutrition, aging, and dysphagia. Dysphagia. 2000;15:31-38.
4) Marik PE, Kaplan D. Aspiration pneumonia and dysphagia in the elderly. Chest 124:328-336, 2003.
5) Lee W, Nagubadi S, Kryger MH, Mokhlesi B. Epidemiology of Obstructive Sleep Apnea: a Population-based Perspective. Expert Rev Respir Med 2:349-64, 2008.
6) Punjabi NM. The epidemiology of adult obstructive sleep apnea. Proc Am Thorac Soc 5:136-43, 2008.
7) Young T, Peppard PE, Gottlieb DJ. Epidemiology of obstructive sleep apnea: a population health perspective. Am J Respir Crit Care Med 165:1217-1239, 2002.
8) Mansfield D, Naughton MT. Obstructive sleep apnoea, congestive heart failure and cardiovascular disease. Heart Lung Circ 14 Suppl 2:S2-7, 2005.
9) Lurie A. Cardiovascular disorders associated with obstructive sleep apnea. Adv Cardiol 46:197-266, 2011.
10) Maeder MT, Schoch OD, Rickli H. A clinical approach to obstructive sleep apnea as a risk factor for cardiovascular disease. Vasc Health Risk Manag 12:85-103, 2016.
11) Sánchez-de-la-Torre M, Campos-Rodriguez F, Barbé F. Obstructive sleep apnoea and cardiovascular disease. Lancet Respir Med 1:61-72, 2013.
12) Butler SG, Stuart A, Leng X et al. The relationship of aspiration status with tongue and handgrip strength in healthy older adults. J Gerontol A Biol Sci Med Sci 66:452-458, 2011.
13) Buehring B, Hind J, Fidler E et al. Tongue strength is associated with jumping mechanography performance and handgrip strength but not with classic functional tests in older adults. J Am Geriatr Soc 61:418-422, 2013.
14) Maeda K, Akagi J. Decreased tongue pressure is associated with sarcopenia and sarcopenic dysphagia in the elderly. Dysphagia 30:80-7, 2005.
15) Utanohara Y, Hayashi R, Yoshikawa M, et al. Standard values of maximum tongue pressure taken using newly developed disposable tongue pressure measurement device. Dysphagia 23:286-290, 2008.
16) Doherty TJ. The influence of aging and sex on skeletal muscle mass and strength. Curr Opin Clin Nutr Metab Care 4:503-508, 2001.
17) Lang T, Streeper T, Cawthon P, et al. Sarcopenia: etiology, clinical consequences, intervention, and assessment. Osteoporos Int 21:543-59, 2010.
18) Teramoto S, Fukuchi Y, Sasaki H et al. High incidence of aspiration pneumonia in community- and hospital-acquired pneumonia in hospitalized patients: a multicenter, prospective study in Japan. J Am Geriatr Soc 56:577-579, 2008.
19) Remmers JE, deGroot WJ, Sauerland EK, Anch AM. Pathogenesis of upper airway occlusion during sleep. J Appl Physiol Respir Environ Exerc Physiol 44:931-938, 1978
20) Kanezaki M, Ogawa T, Izumi T. Tongue protrusion strength in arousal state is predictive of the airway. Tohoku J Exp Med 236:241-245, 2015.
21) Hayashida H, Saito T, Kawasaki K et al. Association of periodontitis with carotid artery intima-media thickness and arterial stiffness in community-dwelling people in Japan: the Nagasaki Islands study. Atherosclerosis 229:186-191, 2013.
22) Kikutani T, Tamura F, Nishiwaki K et al. Oral motor function and masticatory performance in the community-dwelling elderly. Odontology 97:38-42, 2009.