

# BMJ Open Social networks, leisure activities and maximum tongue pressure: cross-sectional associations in the Nagasaki Islands Study

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## ABSTRACT

**Objectives** Social environment is often associated with health outcomes, but epidemiological evidence for its effect on oral frailty, a potential risk factor for aspiration, is sparse. This study aimed to assess the association between social environment and tongue pressure, as an important measure of oral function. The study focused on family structure, social networks both with and beyond neighbours, and participation in leisure activities.

**Design** A population-based cross-sectional study.

**Setting** Annual health check-ups in a rural community in Japan.

**Participants** A total of 1982 participants, all over 40 years old. Anyone with missing data for the main outcome (n=14) was excluded.

**Outcome measures** Tongue pressure was measured three times, and the maximum tongue pressure was used for analysis. A multivariable adjusted regression model was used to calculate parameter estimates (B) for tongue pressure.

**Results** Having a social network involving neighbours (B=2.43, P=0.0001) and taking part in leisure activities (B=1.58, P=0.005) were independently associated with higher tongue pressure, but there was no link with social networks beyond neighbours (B=0.23, P=0.77). Sex-specific analyses showed that for men, having a partner was associated with higher tongue pressure, independent of the number of people in the household (B=2.26, P=0.01), but there was no association among women (B=-0.24, P=0.72; P-interaction=0.059).

**Conclusions** Having a social network involving neighbours and taking part in leisure activities were independently associated with higher tongue pressure. Marital status may be an important factor in higher tongue pressure in men.

## INTRODUCTION

The proportion of people aged 60 years or over is expected to rise from 12% to 22% of the total global population between 2015 and 2050.<sup>1</sup> In Japan, it was already 33% in 2015 and is still rising.<sup>2</sup> Pneumonia is the third most common cause of death in Japan,<sup>2</sup>

## Strengths and limitations of this study

- This is the first study of which we are aware to examine a possible association between tongue pressure and social environment among population-based samples.
- Social environment was measured using a unique approach, focusing on family structure, social networks both with neighbours and beyond, and leisure activities, using simple questions.
- Detailed information about social networks and leisure activities, including quality and quantity of social networks, or type of activities, was not available.
- Social environment data were self-reported, and may therefore reflect a point in time, rather than a long-term situation.
- Causal relationships cannot be inferred because of the cross-sectional design.

and often results in reduced quality of life for both patients with pneumonia and their families, as well as high medical costs.<sup>2,3</sup> The vast majority (97%) of pneumonia deaths in Japan in 2015 were among those aged 65 years or over,<sup>2</sup> and most cases hospitalised for pneumonia were aspiration pneumonia.<sup>4</sup> Dysphagia is a main cause of aspiration,<sup>5</sup> and a susceptible condition for development of pneumonia in older people. A recent systematic review of high-quality studies reported that estimated mean prevalence of dysphagia among community-dwelling older people is 15%.<sup>6</sup> Dysphagia and related aspiration pneumonia prevention for both older people and younger populations is therefore a public health priority in Japan and is expected to be an important issue in other countries.

Social environment refers to the immediate physical surroundings, social relationships and cultural milieus within which defined groups of people function and interact,<sup>7</sup> and

which has a strong influence on physical and psychological health.<sup>8</sup> ‘Social network’ is part of the social environment, covering the structure of relationships, both quality and quantity,<sup>9–10</sup> including family relationships. For example, family members could have a strong influence on health<sup>11</sup> through lifestyle factors such as diet, economic situation, living environment, behaviour or emotions. Having a small social network has been linked to higher risk of mortality<sup>12–13</sup> and incidence of cardiovascular diseases (coronary heart disease,<sup>12–14</sup> heart failure<sup>15</sup> and stroke<sup>10–13</sup>). Having fewer social interactions may be associated with earlier onset of physical and/or cognitive functional disability.<sup>16</sup> Although some population-based studies have suggested that social relationships were associated with oral health, including number of teeth remaining, tooth decay and periodontitis,<sup>17–18</sup> evidence of their effect on tongue pressure is sparse. Tongue pressure is essential to mix food and saliva into a bolus and pass it to the pharynx, which is an important phase in the feeding and swallowing process.<sup>19–20</sup> The tongue also has important functions in daily activities and communications because tongue movement controls articulation and pronunciation.<sup>21</sup>

Lower oral function is related to dysphagia and subsequent aspiration pneumonia.<sup>22</sup> Risk factors for dysphagia include age, existence of lung diseases, stroke,<sup>23</sup> dementia, Parkinson’s disease, low tongue pressure, tooth loss, diabetes or xerostomia,<sup>24</sup> use of hypertension medication, antipsychotic drugs and malnutrition.<sup>6</sup> Bad oral health and poor oral hygiene have been linked to the development of aspiration pneumonia,<sup>24–25</sup> and oral care has been reported as a preventive factor.<sup>25</sup>

Previous experimental studies have shown that lingual exercise<sup>26</sup> had a positive influence on tongue function assessed by isometric and swallowing pressures, and lingual volume. No study, however, has examined whether social environment and daily activities are associated with tongue pressure as a potential risk factor for dysphagia and aspiration. Dysphagia and risk of aspiration can be evaluated in a hospital, measuring swallowing function by videofluoroscopic examination and videoendoscopic evaluation of swallowing, but these techniques are not useful for screening in a community. Tongue pressure measurement has recently been identified as a useful proxy for risk of aspiration,<sup>27–28</sup> as it assesses tongue motor function. Good reproducibility and high correlations of this measurement with other objective measurements for oral function (eg, the repetitive saliva swallowing test, speech intelligibility test, oral diadochokinesis and capacity of tongue-holding and movement test)<sup>21</sup> and symptoms of dysphagia<sup>28</sup> have been reported.

We hypothesised that social environment and daily activities may influence tongue pressure, because having social networks and taking part in leisure activities may increase opportunities to move the tongue. We also hypothesised that there may be sex differences in those associations because of possible biological sex differences<sup>29</sup> and cultural gender roles in Japan, where men work outside

the home, and women tend to be more involved in household chores.<sup>30</sup> In such a culture, social environments could differ by sex. Using data from the Nagasaki Islands Study, we tested the hypotheses that people’s social environment, including their family structure, social networks with and beyond their neighbours, and participation in leisure activities would be positively associated with higher tongue pressure, independent of physical, psychological and behavioural risk factors for dysphagia.

## METHODS

### Study sample

The Goto city municipal government provides annual health check-ups for all residents aged 40 years or older. These check-ups take place in community centres within walking distance of each person’s home. The Nagasaki Islands Study collaborated with the local government to conduct research, mainly targeting atherosclerosis diseases and frailty, by providing additional examinations.<sup>31</sup> In this study, every family unit in Tamanoura and Naru districts in 2015, and Tomie, Kishuku, Miiraku and Hisaka districts in 2016 was informed about the additional examinations by flyers before the study (n=11 741). All 2103 residents who attended the annual health check-ups received an initial invitation to participate in the Nagasaki Islands Study (response rate=17.9%). Of the 2103 participants, 1982 (821 men and 1161 women) participated in this study (agreement rate=94.2%). The Nagasaki Islands Study included maximum tongue pressure measurements. For this cross-sectional analysis, we excluded participants without data on tongue pressure (n=14), resulting in a final sample for analysis of 815 men and 1153 women (see online supplemental figure 1).

### Measures

#### Tongue pressure measurement

The tongue pressure measurement device (JMS Co, TPM-01) was used during health check-ups to evaluate a part of qualitative oral function by measuring maximum tongue pressure. The TPM-01 is a newly developed handheld manometry device, using a small balloon-type disposable oral probe with a plastic pipe, which is placed on the upper surface of the tongue. The TPM-01 is approved as the first medical device for tongue pressure measurement in Japan in 2010.<sup>21</sup> The measurements by the device were closely equivalent to those of the other widely used tongue pressure manometers, the Iowa Oral Performance Instrument, and the stable adhered three air-filled bulbs manometry system of the KayPENTAX Digital Swallowing Workstation.<sup>32</sup> As a zero calibration, the probe was inflated with air at a pressure of 19.6 kPa.<sup>32</sup> Measurement was performed in a relaxed sitting position, and participants were asked to compress the small balloon to the palate as hard as they could, using their tongue. The maximum value was recorded automatically and displayed on the device.<sup>32</sup> The measurement was

performed three times, and the maximum tongue pressure was used for analysis.

### Social environment assessment

Social environment was assessed using a questionnaire about participants' social networks and daily activities. We asked about participants' family household structure, social networks with their neighbours and beyond, and participation in leisure activities. Family household structure was assessed by number of family members in the household, and marital status. Participants were asked whether they were married, divorced, separated or unmarried, and responses were classified dichotomously as married (having a partner) or not. Social networks were assessed by asking 'Do you have any close neighbors with whom you can talk?' (social network involving neighbours), and 'Do you have any close friends, family or relatives beyond your neighbors whom you visit and who visit you?' (social network beyond neighbours). Leisure activities were assessed by asking 'Do you have any hobbies, interests or leisure activities inside or outside your home?'. Choices for those questions were yes or no. Those three questions about social networks and leisure activities are part of the Frailty Index for Japanese older people.<sup>33</sup>

### Measurement of covariates

Questionnaires were used to obtain information on age, sex, smoking status (current, former or never), alcohol use (current, former or never), physical exercise, psychological distress, medical history and medication use. Physical activity was assessed by asking 'Have you been in the habit of doing exercise that makes you sweat lightly for over 30 min a time, at least twice weekly, for over a year?' and 'In your daily life, do you walk or do an equivalent amount of physical activity for more than one hour a day?'. The choices were yes or no. Participants who answered no for both questions were considered to be physically inactive, and those who answered yes for either as physically active.

Psychological distress was measured using the Japanese version of the Kessler 6 (K6) scale, a quantifier of non-specific psychological distress.<sup>34</sup> Physiological variables were measured by trained technicians. Weight (kg) and height (cm) were measured in light clothes (DC-250; Tanita, Tokyo, Japan). Resting blood pressure was measured using digital devices (HEM-907; Omron, Kyoto, Japan). Hypertension was defined as diastolic blood pressure  $\geq 90$  mm Hg, systolic blood pressure  $\geq 140$  mm Hg and/or self-reported antihypertensive medication use. Diabetes mellitus was defined as haemoglobin A1c  $\geq 6.5\%$ , or use of medication for diabetes. History of stroke and respiratory disease was identified by self-reported medication use or having accessed medical care for those diseases. All measurements are routinely provided for all participants.

### Statistical analysis

Descriptive statistics of covariates and potential mediators, by participants' sex, were generated using Student's *t*-tests and  $\chi^2$  tests. To see sex-specific and age-specific distribution of maximum tongue strength and oral frailty, the proportions of each age group (40–49, 50–59, 60–69, 70–79 and 80 years or over) in each maximum tongue pressure band (<19.9 kPa, 20.0–29.9 kPa, 30.0–39.9 kPa and  $\geq 40$  kPa) were calculated. There is no validated cut-off point for maximum tongue pressure indicating oral frailty.<sup>20–27</sup> Association between marital status and number of family members in the household was assessed by Wilcoxon rank-sum test. We used  $\chi^2$  tests to examine whether there were links between marital status, social networks and leisure activity. Multiple linear regression analysis was used to calculate total and sex-specific parameter estimates (B) for maximum tongue pressure after sequential adjustment for potential confounding variables. We used four sequential models. Model 1 adjusted for age [continuous] and sex; model 2 also adjusted for body mass index [continuous], lifestyle factors (smoking status [categorical], alcohol drinking status [categorical] and physical activity [dichotomous]), psychological distress (K6 score [continuous]) and major risk factors for dysphagia (antihypertensive medicine use, diabetes and history of stroke and respiratory disease [all dichotomous]). The number of family members in the household, marital status, social networks with and beyond neighbours, and participation in leisure activities were included in the models. As marital status may be related to number of family members, we also included number of family members in the household (model 3) and marital status (model 4) separately to avoid overadjustment.

In sensitivity analyses, we excluded participants with a history of stroke or respiratory disease, to avoid the possibility that lower tongue pressure or overall oral function was an after-effect of those diseases. We also examined the sex-specific associations, and tested whether sex modified the relationships of social networks and leisure activities with maximum tongue pressure, by including cross-product terms in the models (model 2). All analyses used SAS V.9.4.

### RESULTS

The 1968 participants in our final sample for analysis were on average 70.6 years old (range 40–95), 59% female and with a mean BMI of 23.4 kg/m<sup>2</sup>. **Table 1** shows the characteristics of participants by sex. The mean (SD) maximum tongue pressure was 32.4 (10.4) kPa in men and 29.8 (9.6) kPa in women (P for difference <0.0001). The tongue pressure was lower among older age groups in both men and women (**figure 1**). A total of 93 (11.4%) men were classified as having a tongue pressure <19.9 kPa, 227 (27.9%) as 20.0 to 29.9 kPa, and 495 (60.7%) as  $\geq 30$  kPa. In women, the figures were 171 (14.8%), 384 (33.3%) and 598 (51.9%). The mean number of family members in the household was greater for men (2.2 people) than women

**Table 1** Participant characteristics according to sex: the Nagasaki Islands Study 2015–2016

Sex category	Women	Men	P for difference	Average maximum tongue pressure, kPa*	
				Women	Men
N	1153	815			
<b>Demographics</b>					
Age, years*	70.4±9.3	70.1±10.3	0.44	–	–
<b>Lifestyle factors</b>					
Physical activity, n (%)					
Inactive	162 (14.1)	146 (17.9)	0.02	30.0±9.0	32.2±11.0
Active	991 (85.9)	669 (82.1)		29.8±9.7	32.5±10.3
Cigarette smoking status, n (%)					
Never	1084 (94.0)	220 (27.0)	<0.0001	29.7±9.7	29.9±10.4
Former	44 (3.8)	428 (20.5)		32.1±10.2	32.7±10.5
Current	25 (2.2)	167 (52.5)		32.0±7.1	35.1±9.7
Alcohol drinking status, n (%)					
Never	910 (78.9)	230 (28.2)	<0.0001	29.3±9.9	31.0±10.1
Former	29 (2.5)	93 (11.4)		30.5±9.7	28.1±11.0
Current	214 (18.6)	492 (60.4)		32.0±8.1	33.9±10.2
<b>Physiological characteristics</b>					
Maximum tongue pressure					
Average, kPa*	29.8±9.6	32.4±10.4	<0.0001	–	–
<20.0 kPa, n (%)	171 (14.8)	93 (11.4)	<0.0001	13.8±4.5	13.7±5.0
20 to 29.9 kPa, n (%)	384 (33.3)	227 (27.9)		25.5±2.9	25.8±2.7
30 to 39.9 kPa, n (%)	452 (39.2)	300 (36.8)		34.8±2.8	34.8±2.7
≥40.0 kPa, n (%)	146 (12.7)	195 (23.9)		44.6±4.0	45.5±5.0
Body mass index, kg/m <sup>2</sup> *	23.2±3.5	23.8±3.0	<0.0001	–	–
Hypertension medication, n (%)					
Yes	540 (46.8)	393 (48.2)	0.54	29.2±10.2	31.9±10.8
No	613 (53.2)	422 (51.8)		30.4±9.1	32.9±10.1
Prevalent diabetes, n (%)†					
Yes	121 (10.5)	117 (14.4)	0.01	30.7±9.7	31.7±10.6
No	1032 (89.5)	698 (85.6)		29.7±9.6	32.5±10.4
History of stroke, n (%)					
Yes	30 (2.6)	39 (4.8)	0.01	29.4±7.7	29.7±10.5
No	1123 (97.4)	776 (95.2)		29.8±9.7	32.6±10.4
History of respiratory disease, n (%)					
Yes	30 (2.6)	25 (3.1)	0.54	30.0±9.9	30.2±9.0
No	1123 (97.4)	790 (96.9)		29.8±9.6	32.5±10.5
<b>Psychological characteristics</b>					
Psychological distress (K6 score)*	1.4±2.7	1.1±2.5	0.01	–	–
<b>Social environments</b>					
Number of family members in the household*					
	2.0±1.0	2.2±0.8	0.001	–	–
Marital status, n (%)					
Having a partner	726 (63.0)	629 (77.2)	<0.0001	30.3±9.5	32.5±10.2
No partner	427 (37.0)	186 (22.8)		29.0±9.8	32.1±11.1
Participation in leisure activities, n (%)					
Yes	945 (82.0)	661 (81.2)	0.67	30.1±9.7	32.8±10.4
No	208 (18.0)	153 (18.8)		28.6±9.3	30.7±10.6

Continued



Table 1 Continued

Sex category	Women	Men	P for difference	Average maximum tongue pressure, kPa*	
				Women	Men
<b>N</b>	<b>1153</b>	<b>815</b>			
Having a social network with neighbours, n (%)					
Yes	1001 (86.8)	660 (81.0)	0.0004	30.2±9.4	33.0±10.3
No	152 (13.2)	155 (19.0)		27.5±10.6	30.0±10.8
Having a social network beyond neighbours, n (%)					
Yes	1062 (92.1)	724 (88.8)	0.01	30.0±9.6	32.7±10.4
No	91 (7.9)	91 (11.2)		28.2±9.9	30.4±10.3

\*Represented as mean±SD.

†Diabetes was defined as haemoglobin A1c ≥6.5%, or medication use for diabetes.

(2.0 people) ( $P=0.001$ ). The proportion of men having a partner was also higher (77% vs 63%) ( $P<0.0001$ ).

### Social environment and maximum tongue pressure among participants

Multivariable adjusted linear regression analysis showed that having a social network involving neighbours and participation in leisure activities were positively associated with higher tongue pressure. The multivariable adjusted parameter estimates (B) were 2.43 ( $P=0.0001$ ) and 1.58 ( $P=0.005$ ) (table 2, model 2). The number of family members in the household, marital status and having a social network beyond neighbours were not associated with maximum tongue pressure. The associations did not change when we included number of family members in the household (model 3) and marital status (model 4) separately.

Using Wilcoxon rank-sum test, the number of family members in the household was larger for participants

with a partner than those without ( $P<0.0001$ ). The average number of family members living in the household was  $2.08\pm 0.93$ , and 87% of participants who were living with someone were married. Using  $\chi^2$  tests, marital status (having a partner) was associated with taking part in leisure activities and having social networks with/beyond neighbours in men (all  $P<0.0001$ ), but not in women. Having social networks with neighbours was associated with taking part in leisure activities and having social networks beyond neighbours in both men and women. Having social networks with/beyond neighbours was also associated with taking part in leisure activities in both sexes.

### Sex-specific association in social environment and maximum tongue pressure

In the sex-specific multivariable adjusted linear regression analyses, the associations between maximum tongue pressure and either social networks involving neighbours

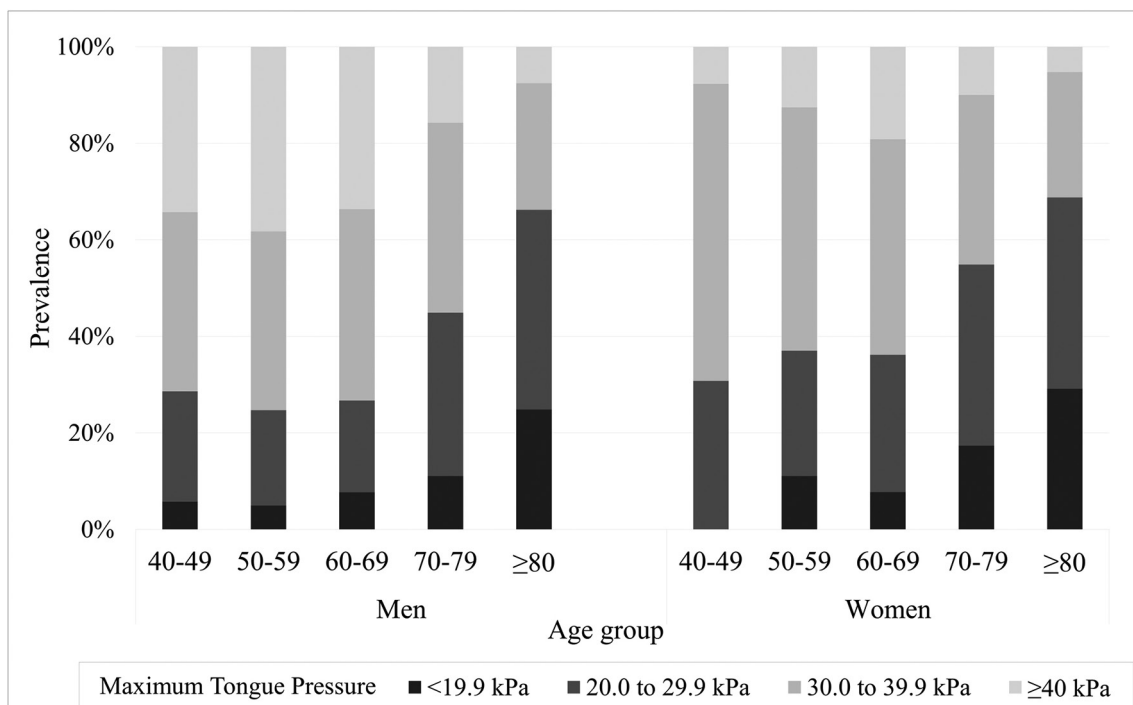


Figure 1 Sex-specific maximum tongue pressure by age group: the Nagasaki Islands Study 2015–2016.

**Table 2** Association of social environments with maximum tongue pressure, the Nagasaki Islands Study 2015–2016

Social environments	Model 1*				Model 2†				Model 3‡				Model 4‡				
	$\beta$	B	95% CI	P value	$\beta$	B	95% CI	P value	$\beta$	B	95% CI	P value	$\beta$	B	95% CI	P value	R <sup>2</sup>
<b>Total</b>																	
Number of family members in the household	-0.04	-0.45	(-0.97 to 0.07)	0.09	0.12	-0.04	(-0.95 to 0.07)	0.09	0.15	-0.03	(-0.78 to 0.15)	0.18	0.15	-	-	-	0.15
Marital status	0.02	0.49	(-0.52 to 1.50)	0.34	0.03	0.59	(-0.42 to 1.59)	0.25	-	-	-	-	0.01	0.30	(-0.62 to 1.21)	0.53	
Participation in leisure activities	<b>0.07</b>	<b>1.90</b>	<b>(0.78 to 3.01)</b>	<b>0.001</b>	<b>0.06</b>	<b>1.58</b>	<b>(0.48 to 2.68)</b>	<b>0.005</b>	<b>0.06</b>	<b>1.60</b>	<b>(0.51 to 2.70)</b>	<b>0.004</b>	<b>0.06</b>	<b>1.61</b>	<b>(0.52 to 2.71)</b>	<b>0.004</b>	
Social network with neighbours	<b>0.09</b>	<b>2.60</b>	<b>(1.35 to 3.85)</b>	<b>&lt;0.0001</b>	<b>0.09</b>	<b>2.43</b>	<b>(1.19 to 3.67)</b>	<b>0.0001</b>	<b>0.09</b>	<b>2.41</b>	<b>(1.18 to 3.65)</b>	<b>0.0001</b>	<b>0.09</b>	<b>2.37</b>	<b>(1.14 to 3.60)</b>	<b>0.0002</b>	
Social network beyond neighbours	0.02	0.55	(-1.01 to 2.11)	0.49	0.01	0.23	(-1.30 to 1.77)	0.77	0.01	0.32	(-1.21 to 1.85)	0.68	0.01	0.36	(-1.17 to 1.88)	0.64	
<b>Women</b>																	
Number of family members in the household	-0.01	-0.13	(-0.77 to 0.51)	0.69	0.08	-0.02	(-0.82 to 0.46)	0.58	0.11	-0.02	(-0.81 to 0.35)	0.44	0.11	-	-	-	0.10
Marital status	-0.02	-0.34	(-1.62 to 0.93)	0.60	-0.01	-0.24	(-1.51 to 1.04)	0.72	-	-	-	-	-0.02	-0.30	(-1.47 to 0.86)	0.61	
Participation in leisure activities	<b>0.06</b>	<b>1.61</b>	<b>(0.18 to 3.03)</b>	<b>0.03</b>	0.06	1.42	(-0.01 to 2.84)	0.05	0.06	1.41	(-0.01 to 2.83)	0.05	0.06	1.41	(-0.02 to 2.83)	0.05	
Social network with neighbours	<b>0.10</b>	<b>2.73</b>	<b>(1.07 to 4.39)</b>	<b>0.001</b>	<b>0.09</b>	<b>2.67</b>	<b>(1.00 to 4.33)</b>	<b>0.002</b>	<b>0.09</b>	<b>2.68</b>	<b>(1.01 to 4.34)</b>	<b>0.002</b>	<b>0.09</b>	<b>2.63</b>	<b>(0.97 to 4.29)</b>	<b>0.002</b>	
Social network beyond neighbours	0.03	1.15	(-0.93 to 3.23)	0.28	0.03	1.17	(-0.90 to 3.23)	0.27	0.03	1.13	(-0.92 to 3.19)	0.28	0.03	1.23	(-0.82 to 3.27)	0.24	
<b>Men</b>																	
Number of family members in the household	<b>-0.08</b>	<b>-1.03</b>	<b>(-1.92 to -0.14)</b>	<b>0.02</b>	0.14	-0.07	(-1.68 to 0.07)	0.07	0.18	-0.03	(-1.17 to 0.44)	0.37	0.17	-	-	-	0.18
Marital status	<b>0.11</b>	<b>2.65</b>	<b>(0.85 to 4.45)</b>	<b>0.004</b>	<b>0.09</b>	<b>2.26</b>	<b>(0.47 to 4.04)</b>	<b>0.01</b>	-	-	-	-	0.06	1.61	(-0.02 to 3.23)	0.05	
Participation in leisure activities	<b>0.08</b>	<b>2.12</b>	<b>(0.35 to 3.90)</b>	<b>0.02</b>	0.06	1.73	(-0.02 to 3.48)	0.05	<b>0.07</b>	<b>1.90</b>	<b>(0.15 to 3.65)</b>	<b>0.03</b>	<b>0.07</b>	<b>1.89</b>	<b>(0.15 to 3.63)</b>	<b>0.03</b>	
Social network with neighbours	<b>0.09</b>	<b>2.43</b>	<b>(0.51 to 4.34)</b>	<b>0.01</b>	<b>0.08</b>	<b>2.13</b>	<b>(0.25 to 4.02)</b>	<b>0.03</b>	<b>0.08</b>	<b>2.14</b>	<b>(0.25 to 4.03)</b>	<b>0.03</b>	<b>0.08</b>	<b>2.04</b>	<b>(0.15 to 3.92)</b>	<b>0.03</b>	
Social network beyond neighbours	-0.01	-0.26	(-2.66 to 2.14)	0.83	-0.03	-1.02	(-3.39 to 1.35)	0.40	-0.02	-0.74	(-3.11 to 1.63)	0.54	-0.03	-0.96	(-3.32 to 1.40)	0.43	

The number of family members in the household, marital status, social networks with and beyond neighbours, and participation in leisure activities were included in models 1–4.

\*Model 1: adjusted for age and sex.

†Model 2: adjusted for model 1 + lifestyle factors (physical activity, smoking status and drinking status) + physiological characteristics (body mass index) + psychological distress (K6 score) + major dysphagia risk factors (antihypertensive medicine use, diabetes, history of stroke and respiratory disease)

‡Models 3 and 4: adjusted for the same variables in model 2 other than number of family members in the household and marital status, which were separately included in models 3 and 4 to avoid overadjustment.

Bolded variables are associated with maximum tongue pressure ( $p < 0.05$ ).  
B, parameter estimate;  $\beta$ , standardised parameter estimate; R<sup>2</sup>, adjusted R-squared

or participation in leisure activities were similar to the combined figures for women and men. The multivariable adjusted B-values were 2.67 ( $P=0.002$ ) and 1.42 ( $P=0.05$ ) for women, and 2.13 ( $P=0.03$ ) and 1.73 ( $P=0.05$ ) for men (table 2, model 2). Having social networks beyond neighbours was not associated with tongue pressure at all, whereas number of family members in the household tended to be negatively associated ( $B=-0.81$ ,  $P=0.07$ ), and marital status (having a partner) was significantly positively associated with higher tongue pressure in men ( $B=2.26$ ,  $P=0.01$ ), but not women ( $B=-0.18$ ,  $P=0.58$ , and  $B=-0.24$ ,  $P=0.72$ ). When we separately included number of family members in the household (model 3) and marital status (model 4), the associations were attenuated in men, but the attenuation did not alter the relationships of social networks and participation in leisure activities with tongue pressure.

In sensitivity analyses excluding participants with stroke or respiratory disease to exclude influences on tongue pressure or overall oral function from those diseases or associated medication, neither the overall nor sex-specific results changed (online supplemental table 1). There was no evidence that sex modified the relationship of number of family members in the household, networks with and beyond neighbours, and leisure activities with maximum tongue pressure (interaction  $P=0.87$ ,  $P=0.36$ ,  $P=0.19$  and  $P=1.00$ ). It did, however, show a borderline significant interaction in the association between marital status and maximum tongue pressure (interaction  $P=0.059$ ).

## DISCUSSION

In this population-based study of 1968 participants, having a social network involving neighbours and participating in leisure activities were associated with higher maximum tongue pressure. This association was independent of age, sex, body mass index, psychological distress, behavioural factors and other risk factors for dysphagia. Having a partner was associated with greater tongue pressure in men only. This is the first evidence of which we are aware that suggests that social environment may influence tongue pressure. It supports previous reports suggesting the importance of social ties and taking part in daily leisure activities in improving or maintaining tongue function and possible prevention of dysphagia and aspiration.

Our results are consistent with previous studies on daily and social activities, in which oral function was assessed by self-reported questionnaire.<sup>35 36</sup> Kamakura *et al* carried out a questionnaire survey among 769 local senior club members, and reported that factors related to daily activities such as time spent outside the home each day, higher frequency of loud laughing and enjoying eating were associated with a lower proportion of swallowing problems (self-reported choking on food).<sup>35</sup> A previous community-based study of 1405 randomly selected older people showed that not participating in social activities was linked to a self-assessed masticatory problem.<sup>37</sup>

Although the mechanisms underlying the association between social networks or participation in leisure activities and tongue pressure have not been fully elucidated, physiological, behavioural and psychological factors are likely to be involved. Higher activity in muscles around the pharynx and mouth may have a positive effect on tongue function. People who are living with family members and have close neighbours may communicate with others more often, and particularly have more opportunity to eat together, have conversations and laugh. Eating with someone could have a positive influence on oral function via increased saliva production and higher tongue activity, as well as having a preventive effect on depression.<sup>38</sup> It may also be related to better nutrition, eating behaviour, dietary composition and energy levels,<sup>39</sup> as well as more social interactions.<sup>40</sup> A link was identified between laughter and enjoying eating and lower self-reported symptoms of aspiration in an epidemiological study.<sup>35</sup>

The difference in frequency of social interactions in daily life could explain why only social networks involving neighbours, and not those beyond, were associated with higher tongue pressure in this study. The influence of social networks beyond neighbours on tongue pressure could depend on both the type of relationship (close family, wider relatives or friends) and frequency of meeting, but the results suggest a possibility that an effective public health intervention to prevent oral frailty and subsequent aspiration might focus on social networks involving neighbours. Hikichi *et al* reported that community intervention may be effective in encouraging social participation among Japanese older people, and helping to prevent the onset of functional disability.<sup>16</sup> That study confirmed that the number of community-based centres for older people, the so-called 'community salons', within 350 m of the home was related to frequency of participation. It also found that incidence of functional disability among residents who participated in community salons three or more times over the 4.9 years of follow-up was reduced by 50% over those who participated twice or less. The result was similar even when the researchers accounted for the possibility of selection bias by using propensity score matching analysis and instrumental variable analysis.<sup>16</sup>

The number of family members in the household was not associated with tongue pressure in the combined analysis, and a negative association was observed in men. We think that this may be partially because of possible differences in duration of living with family members. There is also a possibility of reverse causation: some people may have started to live with family members as a result of decreased ability to perform activities of daily living. We did not collect any detailed information about leisure activities, but these could be related to higher social interaction, physical/mental activity, self-actualisation or 'ikigai', a comprehensive Japanese concept encompassing the 'meaning of life' and/or 'purpose in life'.<sup>41</sup> Large population-based longitudinal studies of older people in

Japan have reported that having hobbies or social participation may be effective in decreasing the risk of functional disability,<sup>42</sup> and progression of senility associated with dementia.<sup>43</sup> A previous report from the Japanese government showed that people with more friends had a stronger feeling of *Ikigai*.<sup>36</sup> The proportion participating in leisure activities was higher in participants with social networks both with and beyond neighbours in our study, but we believe the associations with higher tongue pressure are likely to be independent. The reason for the sex difference in the association between marital status and tongue pressure is unknown, but cultural gender roles in Japan and health-related behaviours could partially mediate the association. As men more often work outside the home, and women are more involved in household chores in Japan,<sup>30</sup> women may have more opportunity to communicate with their neighbours than men, regardless of marital status. Our results suggested that the proportion having social networks and participating in leisure activities were higher among married men than unmarried. Health-compromising behaviours (eg, smoking, heavy drinking, lower vegetable consumption and less frequent dental visits) have previously been shown to be related to marital status in both men<sup>44 45</sup> and women.<sup>45 46</sup> Marital termination (eg, divorce and widowhood) was associated with an elevated mortality risk for men, but not for women in a large Japanese cohort study.<sup>47</sup>

The association between tongue pressure and both social networks and participation in leisure activities was independent of psychological distress in this study. Psychological distress could influence oral function via lower frequency and number of communications, related to reduced social interaction,<sup>48</sup> as well as altered health-promoting behaviours (eg, brushing teeth, consuming a healthy diet, exercising and not smoking). Medication use for depression is also known to be a risk factor for dysphagia and aspiration because of the muscle relaxant effect. A future study examining links with medication use for depression may be helpful.

### Strengths and limitations

Our study had several limitations. Social networks and participation in leisure activities were assessed using a dichotomous answer, so detailed information about the social network quality (eg, relationship or closeness) and quantity (eg, number involved in the social network, and frequency of communications), or the type of activity (eg, solo or social activity) were not available in this study. However, the simplicity of the question is useful in identifying people with at least one social network or leisure activity. Further studies will be needed to investigate the influence of various detailed aspects of social networks and leisure activities on tongue pressure. Second, measurement error and subsequent misclassification almost certainly occurred, because the social environment data were self-reported. Participants' answers were about their mental and social environment at the point of response, and further studies will therefore be

needed to assess the duration of the situation (eg, how long they have been living alone) and timing (eg, when they lost their partner or retired). Third, tongue pressure measurement has good reproducibility and high correlations with other objective measurements for oral functions,<sup>21</sup> but unmeasured characteristics of the participants like cognitive decline, or oral conditions like denture use could have influenced the measurement. Fourth, although we adjusted for potential confounders including disease-related dysphagia risk (stroke, and respiratory disease), there may have been other residual or unmeasured confounders (for example, other diseases like dementia, epilepsy, medication use including anticholinergics, diuretics, antidepressant or sleep medicine, and diet and lifestyle changes) that influenced the association between social environment and tongue pressure. Fifth, causal relationships cannot be identified from cross-sectional analyses. There is a possibility of reverse causation or bidirectional relationships.<sup>49</sup> For example, people without oral frailty may maintain larger social networks or participate in more daily activities, or some people could have started to live with family members as a result of weakened physical function, but this cannot be assessed. Sixth, the study response rate was under 20% in the target population in the city, which may have led to selection bias. However, we believe that the high rate of agreement to participate (94%) is likely to have minimised any bias among the population. Seventh, although age-related social environment differences and/or tongue pressure (figure 1) may have influenced the associations, we could not assess the most appropriate age cut-off point for the associations, partly because we have limited population data to explore this. Further research with a larger sample sizes or prospective design would be needed to investigate whether there are age-specific associations. Last, our study subjects were from a rural area in Japan, in which social ties with neighbours could be stronger than those in urban areas. Further research would be needed to assess the generalisability of the study.

The strengths of our study included objective measurement of tongue pressure using population-based samples, a comprehensive assessment of social environment focusing on family structure, social networks within and beyond neighbours, and participation in leisure activities, and standardised data collection for potential risk factors for dysphagia including psychological distress, and physical and behavioural characteristics.

### CONCLUSIONS

Having a social network involving neighbours and taking part in leisure activities were independently associated with higher maximum tongue pressure in a sample of community-dwelling men and women. Marital status may be also an important factor in maintaining tongue pressure among men. Further studies will be needed to assess the impact of particular elements of the social environment on tongue pressure, including social network size,



quality and duration of the situation or type of activities, using a prospective design. This study, however, suggests the importance of family structure including marital status, social networks with and beyond neighbours, and participation in leisure activities for risk assessment of oral frailty.

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