ORIGINAL REPORT: EPIDEMIOLOGIC RESEARCH

Regional Inequalities in Oral Frailty and Social Capital

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Abstract: ***Introduction:*** *Oral frailty leads to poor nutritional status, which, in turn, leads to frailty. This cross-sectional study aimed to determine regional differences in the prevalence of oral frailty and to identify factors associated with oral frailty using 3-level multilevel models.*

Methods: *This study comprised 165,164 participants aged ≥65 y without long-term care requirements in the Japan Gerontological Evaluation Study. The dependent variable was oral frailty, which was calculated based on age, number of teeth, difficulty in eating tough foods, and choking. The individual-level independent variables included sociodemographics, present illness, social participation, frequency of meeting friends, and social capital. The local district-level independent variable was social capital (*n = *1,008) derived from exploratory factor analyses. The municipality-level independent variable was population density (*n = *62). Three-level multilevel Poisson regression analysis was performed to calculate the prevalence ratios (PRs).*

Results: *The prevalence of oral frailty in municipalities ranged from 39.9% to 77.6%. Regarding district-level factors, higher civic participation was significantly associated with a lower probability of oral frailty. At the municipality level, the PR of the rural-agricultural area was 1.17 (95% confidence interval, 1.11–1.23) (reference: metropolitan).*

Conclusion: *These results highlight the usefulness of oral frailty prevention measures in encouraging social participation in rural areas.*

Knowledge Transfer Statement: *The results of the present study showed regional differences in oral frailty. In particular, rural-agricultural areas show higher prevalence rates of oral frailty than those in metropolitan cities. Promoting measures of social participation among older adults may help prevent oral frailty in rural areas.*

Keywords: oral health, mastication, deglutition, aged, surveys and questionnaires, cross-sectional studies

Introduction

Oral frailty has recently been suggested as a novel construct, defined as a decrease in oral function (Dibello et al. 2022). Although it has several international definitions (Parisius et al. 2022), in Japan, the concept of oral frailty was introduced in 2013 to increase awareness of the importance of oral function in the Japanese population (Minakuchi et al. 2018; Watanabe et al. 2020). Oral frailty is defined by the Japan Dental Association as follows: a series of phenomena and processes that lead to changes in various oral conditions (number of teeth, oral hygiene, oral functions) associated with aging, accompanied by decreased interest in oral health, reduced physical and mental reserve capacity, and increased oral frailty leading to eating dysfunction, which deteriorate physical and mental function (Watanabe et al. 2020). Oral

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A supplemental appendix to this article is available online.

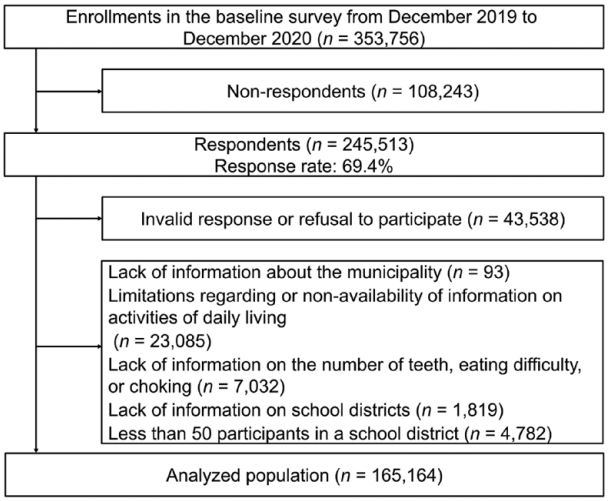
frailty is a major cause of poor nutritional status (Ritchie et al. 2000; Wakai et al. 2010), which is strongly associated with frailty (Iwasaki, Hirano, et al. 2021; Motokawa et al. 2021; Takeuchi et al. 2022). Moreover, it is a risk factor for physical frailty and mortality (Tanaka et al. 2018).

Although oral health inequalities are recognized as an emerging public health issue (Peres et al. 2019; World Health Organization 2022), inequalities in oral frailty remain unclear. Regional inequalities are important from a public health policy perspective. Regional inequalities and individual factors are essential in shaping effective health care policies. Understanding these factors helps to identify health needs, inequalities, and variations in health care utilization among different populations, informing the development of targeted policies and interventions to improve health equity. However, previous studies determining the prevalence of oral frailty have been limited to relatively small populations (Kugimiya et al. 2020; Iwasaki, Watanabe, et al. 2021), because the assessments of some components of oral frailty, such as tongue pressure and articulatory oral motor skills, require special equipment. Therefore, regional inequalities in oral frailty have not yet been evaluated in large populations across countries.

Social capital has gained attention as a modifiable community factor related to health (Murayama et al. 2012). It is also associated with oral health (Batra et al. 2014). Some cross-sectional and longitudinal studies have reported an association between social capital and tooth loss and chewing ability in older adults (Aida et al. 2009; Koyama et al. 2016; Kim et al. 2018). However, the association between social capital and oral frailty remains unclear.

Recently, a formula for determining oral frailty using questionnaires was developed (Yamamoto et al. 2022). No investigations have been conducted to determine the occurrence of oral frailty, variations in its occurrence across different regions, or individual factors used in extensive surveys employing this estimation methodology. The Japan Gerontological Evaluation Study (JAGES) is one of the largest nationwide gerontological questionnaire surveys aimed at understanding the overall status of the older population and how it changes over time (Kondo 2016). Therefore, the present study aimed to examine regional differences in oral frailty and to identify the factors associated with oral frailty.

Figure 1. Flowchart of participant inclusion.



Methods

Study Design and Participants

This cross-sectional study used a self-reported questionnaire. The data were obtained from the JAGES conducted in 2019 and 2020 (Kondo et al. 2018). The JAGES aims to evaluate the social determinants of healthy aging among nondisabled individuals aged ≥65 y. The JAGES 2019 was conducted from December 2019 to December 2020 in 62 municipalities. In 16 of these municipalities, questionnaires were sent to all eligible individuals. In the remaining 46 municipalities, questionnaires were randomly sent to eligible participants. Figure 1 shows a flowchart of participant inclusion. Initially, the questionnaires were distributed to 353,756 individuals, of whom 245,513 responded (response rate, 69.4%). After excluding invalid responses or not agreeing to participate (n = 43,538); lack of information on municipality (n = 93); limitations or no information on activities of daily living (n = 23,085); lack of information on number of teeth, difficulty eating, or choking (n = 7,032); lack of information on local districts (n = 1,819); and <50 participants in local districts (n = 4,782) to avoid nonprecise values due to small samples (Saito et al. 2017), 165,164 eligible participants were included in the analysis (Fig. 1).

Dependent Variable

The dependent variable was the presence or absence of oral frailty, which was calculated using a model to predict oral frailty based on age, number of teeth, difficulty eating tough foods, and choking (Yamamoto et al. 2022). The respondents were instructed to indicate the number of teeth as ≥20, 10 to 19, 1 to 9, or 0, and the number of teeth was categorized as ≥20 and ≤19. Difficulty eating tough foods and choking were determined by asking, "Do you have any difficulties eating tough foods now compared with 6 months previously?" and "Have you recently choked on your tea or soup?" respectively, with possible answers dichotomized into yes and no, as used in the basic checklist for nursing

care prevention in the Japanese long-term care insurance system (Arai and Satake 2015).

Independent Variables

Individual-level independent variables, including sex, age group, marital status, educational attainment, equivalent income, present illness, frequency of meeting friends, social cohesion, and civic participation and reciprocity, were obtained using a self-reported questionnaire. To adjust household income for household size, the equivalent income was calculated by dividing the household income by the square root of the number of household members (Yamamoto et al. 2014). Current medical treatment for hypertension; stroke; heart disease; diabetes; hyperlipidemia; respiratory disease; gastrointestinal, liver, and gallbladder diseases; kidney and prostate disease; musculoskeletal diseases; trauma; cancer; blood and immune diseases; depression; dementia; Parkinson's disease; visual/hearing impairment; or other conditions was used as the variable present illness, which was dichotomized into yes and no.

Individual-level social cohesion and civic participation and reciprocity were assessed using methods described in a previous study (Fujihara et al. 2019). Social cohesion was assessed using the following questions: "Do you think individuals in your community are generally trustworthy?" "Do you think individuals in your community often try to be helpful to others?" and "Do you have an attachment to your local area?" The response categories for the social cohesion variable were a yes answer to at least 1 of these 3 questions and a no to all. Civic participation was assessed using the following question: "How often do you participate in a volunteer group, a sports group, or a hobby activity?" The responses were categorized into yes or no based on the participation frequency using the following options: ≥4 times a week, 2 to 3 times a week, once a week, 1 to 3 times a month, a few times a year, and never. The response was categorized as yes if the volunteers participated in any of the 3 groups at least once a month or more and no if there was participation a few times a year or never. Reciprocity was assessed using the following questions: "Do you have someone who listens to your concerns and complaints?" (examining the receipt of emotional support), "Do you listen to someone else's concerns and complaints?" (providing emotional support), and "Do you have someone who looks after you when you are sick?" (receiving instrumental support). The response categories used for reciprocity were a yes to at least 1 of the 3 questions and no to all.

As the local district-level independent variable, local district-level social capital was calculated using factor analysis (Fujihara et al. 2019). First, the rates of each individual-level social capital response in each small district were calculated. Subsequently, taking each of the 1,008 local districts as the units of analysis, exploratory factor analyses were performed, and 3 factors were obtained: civic participation (i.e., participation in a volunteer group, a sports group, and a hobby activity), social cohesion (i.e., community trust and attachment), and reciprocity (i.e., receiving/providing emotional support or receiving instrumental support) (Appendix Table 1). The factor scores for each community were used as variables for local district-level social capital.

Population density was used as a municipality-level independent variable. Population density (people/km^2) was obtained by dividing the overall population by municipal area (ha converted into km^2). We defined areas with a population density <1,000 people/km^2 as rural-agricultural, 1,000 to 1,499 people/km^2 as semiurban, 1,500 to 3,999 people/km^2 as urban, and ≥4,000 people/km^2 as metropolitan.

Statistical Analyses

Categorical variables that included missing values were recorded by reassigning missing values to separate "data missing" categories to maximize the number of participants included in the statistical analysis and thereby maximize statistical power. The prevalence of oral frailty in each municipality was calculated. The association between oral frailty and individual- and municipality-level independent variables was assessed using the χ^2 test. A 3-level multilevel Poisson regression model with random intercepts and fixed slopes was used to calculate the multilevel prevalence ratios (PRs) and their 95% confidence intervals (CIs), considering variations in the prevalence of oral frailty between local districts and municipalities. In model 1, each individual-, local district-, and municipality-level variable was added separately to the 3-level multilevel model. In model 2, only sex and age were added. In model 3, all the independent variables were added. We also calculated the PR values when the dependent variable in the multilevel model was changed from oral frailty to ≤19 teeth, difficulty eating tough foods, and choking, which were the oral health indicators used in the oral frailty estimation equation.

Statistical analyses, other than multilevel analyses, were performed using IBM SPSS Statistics (version 27; SPSS Japan, Inc.). Multilevel analyses were performed using MLwiN 3.06 (Centre for Multilevel Modelling, University of Bristol), with a significance level of 5%.

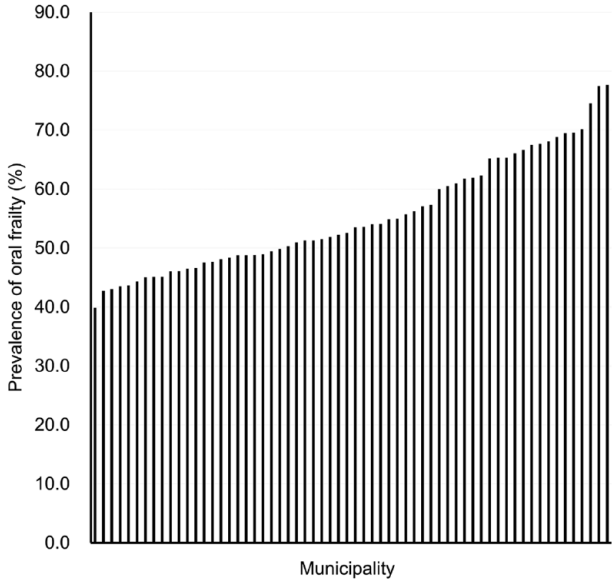
Ethical Issues

The JAGES 2019 survey was approved by the Ethics Committee of the National Center for Geriatrics and Gerontology (No. 1274-2) and Chiba University (No. 3442). Informed consent was obtained from all the participants. In addition, we adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement to report our observational study.

Results

The prevalence of oral frailty in the 62 municipalities is shown in Figure 2. The

Figure 2. Prevalence of oral frailty in 62 municipalities.



prevalence ranged from 39.9% to 77.6%, with a median of 53.0%.

Table 1 shows the association between oral frailty and individual and municipal characteristics. Participants with oral frailty were characterized by male sex, older age, separated/divorced status, lower educational attainment, lower equivalent income, having present illness, lower frequency of meeting friends, lack of social cohesion, civic participation and reciprocity, and living in rural-agricultural municipalities.

The results of the multilevel Poisson regression analysis are presented in Table 2. In model 1, all individual-, local-, and municipality-level variables were significantly associated with oral frailty. The municipality- and local district-level variances (standard errors) of the null model were 0.026 (0.005) and 0.001 (0.000), respectively. In model 2, both sex and age were significantly associated with oral frailty. However, both the municipality- and local district-level variances were similar to those of the null model. Among individual-level factors in model 3, male sex, older age, separated/divorced status, lower educational attainment, lower equivalent income, having present illness, lower frequency of meeting friends, lack of social cohesion, and civic participation and reciprocity were significantly associated with oral frailty. In terms of district-level factors, higher civic participation was significantly associated with a lower probability of oral frailty among older adults living there. At the municipality level, the PR of the rural-agricultural area was 1.17 (95% CI, 1.11–1.23) (reference: metropolitan).

The PRs for each component of oral frailty in the individual-, local district-, and municipality-level parameters, calculated using multilevel Poisson regression models, are shown in Appendix Table 2. The PRs for female sex and the dependent variables of ≤19 teeth and difficulty eating were 0.85 and 0.91, respectively, but it was 1.06 for choking. In the model where the dependent variable was ≤19 teeth, the frequency of rarely meeting friends was significantly higher only compared with ≥4 times per week. However, in the model where the dependent variable was difficulty eating hard foods and choking, it was significantly higher even when the frequency was 2 to 3 times per week. The PRs for individual-level civic participation and reciprocity in the model where the dependent variable was ≤19 teeth and difficulty eating were statistically significant. However, the PR in the model where the dependent variable was choking was not. The PRs for local district-level civic participation in the model where the dependent variable was ≤19 teeth and difficulty eating were statistically significant. However, the PR in the model where the dependent variable was choking was not. At the municipality level, the PR in rural-agricultural area in the model where the dependent variables were ≤19 teeth and difficulty eating was statistically significant. However, the PR in the model where the dependent variable was choking was not.

Discussion

To the best of our knowledge, this is the first study to examine regional differences in oral frailty. The results of the present study showed a nearly 2-fold difference in the prevalence of oral frailty among municipalities. In particular, municipalities in rural-agricultural areas had higher prevalence rates of oral frailty than those in metropolitan cities. These results indicate that rural-agricultural municipalities are the target areas where oral frailty measures should be strengthened.

The results of the present study demonstrated that living in communities with higher community-level civic participation was associated with a lower prevalence of oral frailty, even after adjusting for possible confounders, including individual-level social capital. These results are consistent with those of previous studies on the association between community-level civic participation and number of teeth (Aida et al. 2009; Koyama et al. 2016), which is the main component of oral frailty (Yamamoto et al. 2022). In a cross-sectional study of older adults, adults living in areas with greater participation in volunteering, sports, and hobbies were more likely to have more teeth, even after adjusting for individual-level civic participation, than their counterpart (Aida et al. 2009). In another longitudinal study, older adults living in areas with

Table 1.
Association of Individual and Municipality Characteristics with Oral Frailty ($n = 165,164$).

Characteristics	Categories	Total	With Oral Frailty	
		n	*n*	%
Sex	Male	79,906	43,162	54.0
	Female	85,258	42,149	49.4
Age group, y	65–69	42,419	15,087	35.6
	70–74	50,036	21,172	42.3
	75–79	40,298	25,541	63.4
	80–84	22,474	15,692	69.8
	≥85	9,937	7,819	78.7
Marital status	Married	120,400	59,036	49.0
	Separated/divorced	36,083	21,646	60.0
	Never married	5,104	2,368	46.4
	Unknown/data missing	3,577	2,261	63.2
Educational attainment, y	≤9	39,102	25,964	66.4
	10–12	71,366	35,874	50.3
	≥13	50,420	21,035	41.7
	Data missing	4,276	2,438	57.0
Equivalent income, 10,000 Japanese yen	0–199	69,242	39,784	57.5
	200–399	57,886	26,235	45.3
	≥400	17,615	7,225	41.0
	Data missing	20,421	12,067	59.1
Current illness	No	31,227	14,039	45.0
	Yes	127,789	68,159	53.3
	Data missing	6,148	3,113	50.6
Frequency of meeting friends	≥4 times/wk	24,231	11,804	48.7
	2–3 times/wk	31,452	15,994	50.9
	Once/wk	21,160	10,553	49.9
	1–3 times/mo	39,244	19,767	50.4
	Several times a year	32,541	16,931	52.0
	Rarely	12,924	8,004	61.9
	Data missing	3,612	2,258	62.5
Social cohesion	No	20,618	11,450	55.5
	Yes	142,100	72,390	50.9
	Data missing	2,446	1,471	60.1

(continued)

Table 1.
(continued)

Characteristics	Categories	Total	With Oral Frailty	
		n	*n*	%
Civic participation	No	75,295	40,771	54.1
	Yes	71,457	32,899	46.0
	Data missing	18,412	11,641	63.2
Reciprocity	No	1,943	1,218	62.7
	Yes	161,373	82,933	51.4
	Data missing	1,848	1,160	62.8
Population density	Metropolitan	63,832	30,195	47.3
	Urban	24,411	11,442	46.9
	Semiurban	24,666	12,762	51.7
	Rural-agricultural	52,255	30,912	59.2

All *P* values are <0.001, χ^2 test.

higher civic participation had a lower risk of tooth loss, even after adjusting for individual-level civic participation, than their counterpart (Koyama et al. 2016). Although these studies have focused on the number of teeth, the present study focused on oral function in addition to the number of teeth, to reveal a similar association. These results indicate that promoting measures of civic participation among older adults may help prevent oral frailty. In fact, creating a place for older individuals to go to in the community encourages civic participation and improves their oral function (Tsuji et al. 2022).

The causal relationship remains uncertain because of the cross-sectional nature of this study. Nevertheless, there are various conceivable justifications for the lower prevalence of individuals with oral frailty in regions with heightened civic participation. Civic participation is an aspect of social capital, and the pathways linking social capital and oral health include behavioral and psychosocial, access to oral health services, and policy development (Rouxel et al. 2015). In the context of the behavioral pathway, civic participation affects health behaviors through mechanisms, such as social contagion and informal social control. For instance, 1 study observed the diffusion of smoking cessation through social networks (Christakis and Fowler 2008). Therefore, social contagion may explain the association between community-level civic participation and absence of oral frailty, making it easier for older adults to obtain useful information on oral health behaviors.

The results of the present study suggest that community-level civic participation is more closely associated with oral frailty than other aspects of social capital, such as social cohesion and reciprocity. Saito et al. (2017) have reported that civic engagement displays a stronger association with favorable health consequences compared with community-level social cohesion. This is likely attributable to the latter being gauged through more objective means, leading to a reduced measurement bias arising from the exclusion of individuals who distrust others within the community. Collective efficacy in communities with more active civic participation can prevent oral frailty through better-connected residents and substantial access to oral health services. Social contagion and collective efficacy are important pathways linking community-level civic participation to the prevention of oral frailty but may not pertain to pathways linking community-level social cohesion and reciprocity to the prevention of oral frailty. The low prevalence of oral frailty in areas with higher population densities (i.e., metropolitan cities) may be due to the increased availability of services and transportation, which can prevent oral frailty.

In this study, older adults living in densely populated areas had higher social participation than their counterpart. The percentages of civic participation in metropolitan, urban, semiurban, and rural-agricultural areas were 48.8%, 47.1%, 40.7%, and 36.2%, respectively ($P < 0.001$, χ^2 test) (data not shown). The mean (standard deviation) factor scores for civic participation for metropolitan, urban, semiurban, and rural-agricultural area were 0.39 (0.73), 0.26 (0.55), –0.39 (0.82), and –0.79 (0.74), respectively ($P < 0.001$, 1-way analysis of variance) (data not shown). These results also indicate that promoting civic participation among older adults in rural

Table 2.
Prevalence Ratios for Oral Frailty in Individual-, Local District-, and Municipality-Level Parameters Calculated Using a Multilevel Poisson Regression Model ($n = 165,164$).

Fixed and Random Effects	Categories	Model 1			Model 2			Model 3		
		PR	95% CI	*P* Value	PR	95% CI	*P* Value	PR	95% CI	*P* Value
Fixed effects										
Individual level										
Sex	Male	1.00	(reference)		1.00	(reference)		1.00	(reference)	
	Female	0.91	(0.90–0.92)	<0.001	0.91	(0.90–0.93)	<0.001	0.89	(0.87–0.90)	<0.001
Age group, y	65–69	1.00	(reference)		1.00	(reference)		1.00	(reference)	
	70–74	1.22	(1.20–1.25)	<0.001	1.22	(1.20–1.25)	<0.001	1.19	(1.17–1.22)	<0.001
	75–79	1.83	(1.79–1.87)	<0.001	1.83	(1.79–1.87)	<0.001	1.74	(1.70–1.77)	<0.001
	80–84	1.99	(1.95–2.04)	<0.001	1.99	(1.95–2.04)	<0.001	1.85	(1.81–1.89)	<0.001
	≥85	2.21	(2.15–2.28)	<0.001	2.21	(2.15–2.27)	<0.001	1.99	(1.93–2.05)	<0.001
Marital status	Married	1.00	(reference)					1.00	(reference)	
	Separated/ divorced	1.21	(1.19–1.23)	<0.001				1.10	(1.08–1.12)	<0.001
	Never married	0.95	(0.91–0.99)	0.013				0.99	(0.95–1.03)	0.525
	Unknown/data missing	1.25	(1.20–1.30)	<0.001				1.08	(1.04–1.14)	0.001
Educational attainment, y	≤9	1.00	(reference)					1.00	(reference)	
	10–12	0.77	(0.76–0.78)	<0.001				0.91	(0.90–0.93)	<0.001
	≥13	0.65	(0.64–0.66)	<0.001				0.81	(0.79–0.83)	<0.001
	Data missing	0.86	(0.83–0.90)	<0.001				0.90	(0.86–0.94)	<0.001
Equivalent income, 10,000 Japanese yen	0–199	1.00	(reference)					1.00	(reference)	
	200–399	0.81	(0.80–0.82)	<0.001				0.89	(0.88–0.91)	<0.001
	≥400	0.74	(0.72–0.75)	<0.001				0.85	(0.83–0.87)	<0.001
	Data missing	1.00	(0.98–1.02)	0.961				0.97	(0.95–0.99)	0.014
Current illness	No	1.00	(reference)					1.00	(reference)	
	Yes	1.18	(1.15–1.20)	<0.001				1.07	(1.05–1.09)	<0.001
	Data missing	1.11	(1.07–1.16)	<0.001				1.05	(1.01–1.09)	0.020
Frequency of meeting friends	≥4 times/wk	1.00	(reference)					1.00	(reference)	
	2–3 times/wk	1.04	(1.02–1.07)	<0.001				1.02	(1.00–1.04)	0.101
	Once/wk	1.03	(1.00–1.05)	0.064				1.01	(0.98–1.04)	0.499
	1–3 times/mo	1.03	(1.01–1.06)	0.004				1.02	(1.00–1.04)	0.080
	Several times a year	1.07	(1.05–1.10)	<0.001				1.02	(1.00–1.05)	0.101
	Rarely	1.28	(1.24–1.32)	<0.001				1.09	(1.06–1.12)	<0.001
	Data missing	1.24	(1.19–1.30)	<0.001				1.02	(0.97–1.08)	0.397
Social cohesion	No	1.00	(reference)					1.00	(reference)	
	Yes	0.92	(0.90–0.94)	<0.001				0.93	(0.91–0.94)	<0.001
	Data missing	1.07	(1.01–1.13)	0.013				0.98	(0.93–1.04)	0.470

(continued)

Table 2.
(continued)

Fixed and Random Effects	Categories	Model 1			Model 2			Model 3		
		PR	95% CI	*P* Value	PR	95% CI	*P* Value	PR	95% CI	*P* Value
Civic participation	No	1.00	(reference)					1.00	(reference)	
	Yes	0.87	(0.86–0.89)	<0.001				0.90	(0.88–0.91)	<0.001
	Data missing	1.14	(1.12–1.17)	<0.001				1.01	(0.99–1.03)	0.487
Reciprocity	No	1.00	(reference)					1.00	(reference)	
	Yes	0.82	(0.77–0.87)	<0.001				0.92	(0.86–0.97)	0.004
	Data missing	0.98	(0.90–1.06)	0.571				0.94	(0.86–1.04)	0.226
Local district level										
Social cohesion (factor)		0.96	(0.95–0.97)	<0.001				0.99	(0.98–1.01)	0.354
Civic participation (factor)		0.93	(0.92–0.94)	<0.001				0.96	(0.95–0.97)	<0.001
Reciprocity (factor)		0.98	(0.97–0.99)	0.001				1.00	(0.99–1.01)	0.518
Municipality level										
Population density	Metropolitan	1.00	(reference)					1.00	(reference)	
	Urban	1.00	(0.91–1.10)	0.958				0.99	(0.93–1.05)	0.795
	Semiurban	1.10	(1.09–1.21)	0.060				1.05	(0.99–1.11)	0.131
	Rural-agricultural	1.28	(1.19–1.38)	<0.001				1.17	(1.11–1.23)	<0.001
Intercept					0.39	(0.37–0.41)	<0.001	0.47	(0.44–0.51)	<0.001
Random effects										
Local district-level variance (SE)		0.001	(0.000)		0.000	(0.000)		0.000	(0.000)	
Municipality-level variance (SE)		0.026	(0.005)		0.026	(0.005)		0.004	(0.001)	

Model 1: Each individual-, local district-, and municipality-level variable was added separately to the 3-level multilevel model. The values of the random effects were those for the null model. Model 2: Sex and age groups were added simultaneously to the 3-level multilevel model. Model 3: All individual-, local district-, and municipality-level variables were added simultaneously to the 3-level multilevel model.
CI, confidence interval; PR, prevalence ratio; SE, standard error.

agricultural areas may help prevent oral frailty.

The association between local district-level civic participation and the number of teeth and masticatory ability was significant, but not for choking, which constitutes the estimated equation for oral frailty (Yamamoto et al. 2022). A decline in masticatory ability is strongly influenced by a decrease in the number of teeth (Gotfredsen and Walls 2007). The main causes of permanent tooth loss are dental caries and periodontal diseases (Aida et al. 2006). The prevalence of dental caries and periodontal disease varies with health behaviors, and the social determinants of health behaviors influence them from childhood and throughout life (Peres et al. 2019). Choking may not have such factors, such as the number of teeth; however, this requires further study in the future. Tooth loss and masticatory dysfunction were more common in men than in women, whereas choking was more common in women than in men (Appendix Table 2). Social participation was more common in women (48.9%) than in men (37.3%), and the association was statistically significant ($P < 0.001$, χ^2 test) (data not shown). This may have affected the difference in the association: the association between local district-level civic participation and the number of teeth and masticatory ability was significant, but not for choking.

The factors significantly associated with oral frailty in this study were also significantly associated with number of teeth, except for present illness, and the results for oral frailty and number of teeth in the multilevel analysis were similar. A possible explanation for the similar results is that the weight of the number of teeth in the formula for determining oral frailty is greater than that of difficult eating and choking. The gold standard for this formula is a relatively widely used definition of oral frailty (Tanaka et al. 2018). Oral frailty is viewed as a precursor to frailty, and

it has been noted that the number of teeth is the strongest oral predictor of frailty (Tanaka et al. 2018; Dibello et al. 2021). Recently, this definition has been discussed, and mastication, swallowing, oral motor skill, and salivation have been proposed as components of oral frailty, with the number of teeth being excluded from the components (Parisius et al. 2024). It is expected that oral frailty will be reconsidered and the results of this study will be confirmed by further studies, such as revising the weights of difficult eating and choking and adding oral dryness.

The strengths of the present study include its large sample size, population-based sampling, and control of several confounding factors. However, this study has some limitations. First, this was a cross-sectional study. It is impossible to rule out the possibility of reverse causation. Prospective follow-up studies are required to confirm these findings. Second, the response rate was 69.4%; therefore, the results may have been affected by a selection bias. Third, the measurement of oral health status was based on self-reports rather than clinical examinations. However, regarding the self-reported number of teeth, the general population can provide accurate estimates of the self-reported number of teeth present (Pitiphat et al. 2002).

Conclusions

There is a nearly 2-fold difference in the prevalence of oral frailty among 62 municipalities in Japan. In particular, municipalities in rural-agricultural areas show higher prevalence rates of oral frailty than those in metropolitan cities. Living in communities with higher community-level civic participation is associated with a lower prevalence of oral frailty, even after adjusting for possible confounders, including individual-level social capital.

Author Contributions

T. Yamamoto, contributed to conception, design, data analysis and interpretation, drafted and critically revised the manuscript, Y. Mochida, K. Irie, N.U. Altanbagana, S. Fuchida, K. Takeuchi, M. Fujita, contributed to conception, data interpretation, critically revised the manuscript, J. Aida, K. Kondo, contributed to conception, data acquisition and interpretation, critically revised the manuscript. All authors have their final approval and agree to be accountable for all aspects of work.

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