博 士 論 文

The role of food behaviors in frailty and sarcopenia prevention in community-dwelling older adults

(地域在住高齢者のフレイルとサルコペニア予防における食行動の役割)

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Table of contents

Page

List of tables and figures

Tables

Figures

List of appendices

Abstract

Background

Frailty and sarcopenia have become the important geriatric syndromes. However, only few studies explored the relationship between frailty and sarcopenia with food in terms of food behaviors and dietary pattern approach. In this study, I aimed to explore the association between eating alone, one of the common food behaviors, and frailty, together with the association between dietary patterns and sarcopenia, as the main cause of frailty, in Japanese older adults.

Methods

I conducted two cross-sectional studies using data from the Kashiwa study from Chiba prefecture, Japan. Participants were 65 years or over older adults who were non-eligible for long term care. In the first study, I assessed the participants eating and living status using self-reported questionnaire. Kihon Checklist was used to evaluate frail status. In the second study, dietary history was assessed and then it was used to create dietary patterns by principal component analysis. From review of literature, Japanese diet score was also used. Sarcopenia was evaluated by criteria from the Asian Working Group for Sarcopenia. Binary logistic regression analysis was run to explore the associations between food behaviors and frailty or sarcopenia.

Results

Older adults who ate alone despite living with others were more likely to be frail. Eating and living status were associated with different domains among gender. Low prevalence of sarcopenia was associated with adherence to dietary patterns high in foods characteristic of a Japanese diet including fish, soybean products, vegetables, and fruits.

Conclusions

Eating alone was associated with frailty. Also, Japanese diet was associated with low prevalence of sarcopenia. Encouraging practice of commensality and adherence of Japanese diet might be tools in prevention of frailty in community-dwelling older adults.

Keywords: food, older adults, eating alone, dietary pattern, community, frailty, sarcopenia

1. Introduction

1.1. Aging population

Global population is aging. In 2019, global older population reached 703 million people with Eastern and South-Eastern Asia as the home to the largest number of the older population. The global older population is projected to reach 21.1% by 2050 (1). As the demographic structure changes with more older adults, the epidemiology of the disease also changes, resulting in the demand to change medical care system. Older adults often suffer from the process of aging with functional deterioration of multiple organ systems together with lifestyle-related diseases, geriatric syndrome and disability. Thus, integrated and comprehensive medical care, prioritizing to increase the quality of life, is essential (2). With increasing number of aging population, health care and social protection costs are expected to rise. As a result, it is necessary to promote healthy and independent aging to help older adults maintain their functional ability (3).

1.2. Frailty

1.2.1. Concept and definition of frailty

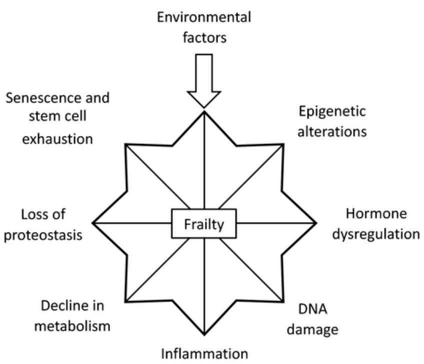
Frailty is defined as a state of increased vulnerability from age-associated decline in reserve and function across multiple physiologic systems resulting in decreased ability to cope with stressors (4). Frailty is different from disability or co-morbidity but these could be coincided (5). Two concepts of frailty are commonly used: the frailty phenotype and the frailty index. The frailty phenotype by Fried et al, using data from the Cardiovascular Health Study, defines frailty as a biological syndrome with the presence of three or more of the five attributes: weakness, slow walking speed, unintentional weight loss, exhaustion and low physical activity (6). The frailty phenotype is widely used but some argued whether other common age-related conditions such as cognitive impairment should be included (7). Whereas, the frailty index conceptualizes frailty as a state provoked by accumulation of health deficits through the life course and the more deficits one has, the more prone one to be frail (8). The deficits are wide-ranging and can include symptoms, signs, diseases, disabilities, laboratory abnormalities and social components (9).

Frailty has become one of the most important geriatric syndromes. A systemic review shows that the prevalence of frailty by the Fried scale in community-dwelling older adults aged 65 years and older varied from 4.9% to 27.3% (10). In Japan, the pooled prevalence of frailty in community is 7.4% and the prevalence becomes higher in older age (11). Frailty is related to various negative health outcomes such as risk of mortality, hospitalization, development of disabilities and using long term care services (12, 13). Frailty is not a part of aging and it is a dynamic process including improvement and natural progression (14). Hence, prevention and early intervention of frailty are essential.

1.2.2. Mechanisms of frailty

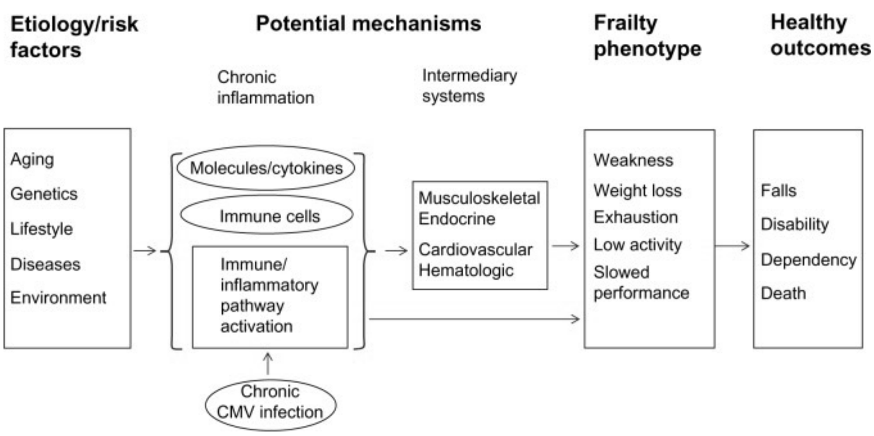
The biological mechanisms of frailty, similar to those of aging, are multifactorial across multiple organ systems. They involve chronic inflammation, loss of stem cell regeneration, DNA damage, a decline in metabolism, endocrine dysfunction, epigenetic factors, and the loss of proteostasis (15, 16). These mechanisms are interrelated. Environmental factors also could provoke or exacerbate these mechanisms. (Fig 1)

Figure 1. Frailty biological mechanisms, Reference (17)



Chronic inflammation is probably the main underlying mechanism that induce frailty. Individual inflammatory molecules, such as IL-6, may directly give rise to frailty or its core components (such as low muscle strength and slowed physical performance). Moreover, chronic inflammation could act through other physiologic organ systems such as musculoskeletal system (osteopenia), hematologic system (anemia), cardiovascular system (cardiovascular diseases), and endocrine system (decreased insulin-like growth factor-1, decreased DHEA-S, and insulin resistance) (18). (Fig 2)

Figure 2. Hypothetical modal pathways leading to frailty, Reference (19)



However, other factors apart from chronic inflammation must have role in development of frailty as well since some studies show no associations between elevated IL-6 and prevalence or incidence of frailty (20, 21). It should be noted that frailty can be influenced by a range of different environmental factors such as smoking and nutritional status (19).

Furthermore, behavioral mal-adaptation is thought to be involved in development of frailty. Behavioral mal-adaptation made according to the declined physiologic reserve could precede an overt state of frailty. One example is life space—the size of the spatial area a person purposely moves through in daily life. Longitudinal research found that in older adult women who left the neighborhood less frequently were more likely to become frail, even after adjustment for chronic disease, physical disability and psychosocial factor (22). This study theorized that the use of external and internal compensatory methods may help decrease the impact of declined physiologic reserve. Thus, restriction of life space is a sign of declined physiologic reserve and restriction of life space itself could lead to decline in physiologic reserve as well.

1.2.3. Frailty measurement

Two main approaches have dominated frailty measurement. First, the frailty phenotype or CHS index defines frailty as the presence of three or more of unintentional weight loss (4.5 kg or more in the last year), weakness (low grip strength), exhaustion (self-reported), slowness (slow walking speed) and low physical activity (6). It is a popular measurement of frailty. The strength of this measurement is the solid foundation of biological causative theory (23). However, it requires the measurement which is not routinely used in clinical evaluation such as grip strength and does not include psychosocial aspect of frailty. Second, the frailty index of clinical deficits (FI-CD) which includes the accumulation of 30 or more co-morbidities, symptoms, diseases, disabilities or any deficiency in health (8). FI-CD is described as a ratio. The strength of FI-CD is higher predictive value of adverse clinical events than other frailty measurements in both hospital and community settings (9, 24). Nevertheless, to calculate the score is time consuming, thus it is not popular in clinical setting (25). Frailty index from a standardized comprehensive geriatric assessment (FI-CGA) which is already collected is more time-efficient (26). Apart from frailty phenotype and frailty index, various tools are being used to measure frailty such as the Study of Osteoporotic Fractures (SOF) index, Edmonton Frailty Scale (EFS), Groningen Frailty Indicator (GFI) and the Kihon Checklist (KCL). In Japan, KCL which has the same concept as the FI-CGA is widely used (27). It consists of 25 items divided into seven categories: physical strength, nutrition, eating, socialization, memory, mood and lifestyle. KCL has been validated and found to be appropriated for cross-cultural study (28).

1.3. Sarcopenia

1.3.1. Concept and definition of sarcopenia

Sarcopenia is an age-related decline in skeletal muscle mass as well as muscle function which could be defined by muscle strength or physical performance (29). It is known to be related with various negative health outcomes such as low quality of life, falls, low physical capability and mortality (30-33). The cause of sarcopenia is multifactorial, including environmental factors, diseases, inflammation, mitochondrial abnormalities, loss of neuromuscular junctions, decreased satellite cells, and hormonal dysfunction (34). Environmental factors are composed of decline in physical activity and decrease nutritional intake. Inadequate protein, low calorie intake and over nutrition are known to increase loss of muscle mass and function, resulting in sarcopenia (35). The definitions of frailty by phenotypes and sarcopenia overlap. Moreover, many of the negative outcomes of frailty might be mediated by sarcopenia (36). Most older adults with frailty had sarcopenia, and older adults with sarcopenia are also frail. However, the general concept of frailty also includes psychological and social dimension (37).

1.3.2. Sarcopenia measurement

Although CT and MRI scan are the gold standard of muscle mass assessment (38), they are expensive and not easy to access in normal clinical setting. Bioelectrical impedance analysis (BIA) and dual-energy X-ray absorptiometry are now used for muscle mass assessment and evidence showed that they are well correlated (39). Various working groups have proposed the criteria for diagnosis of sarcopenia.

The criteria from International Working Group on Sarcopenia (IWGS) and the Special Interest Group on cachexia-anorexia (SIG) comprise of low muscle mass and low physical performance (gait speed) (40, 41). Low muscle strength has been added to diagnostic criteria of sarcopenia by the European Working Group on Sarcopenia in Older People (EWGSOP) and the Asian Working Group on Sarcopenia (AWGS), but with different cut-off points (38, 42). Muscle strength can be assessed by hand grip strength, which is associated with most relavant outcomes of frailty and sarcopenia (43). The other tool is chair stand test. EWGSOP offered various possible tests for physical performance assessment such as usual gait speed, Get-up-and-go test and short physical performance battery (38).

1.4. Food behaviors in older adults

"Food behaviors" are defined as all behaviors related to the acquisition, preparation, serving, consuming, and disposing of food (44). To understand food behaviors, one must think of the product of multiple individual, social, and environmental processes.

Aging is related with factors which can compromise nutritional status such as economic, psychologic, and social changes. Physiologic changes in aging influence the need for several essential nutrients (45). Between 15% and 30% of older adults experience decreased appetite which was described as the anorexia of aging. It is related with being women, living in nursing home, hospitalization and increasing age (46). Anorexia of aging could result in suboptimal intake of nutrients in early stage and develop to inadequate overall nutrient intake and quantitative malnutrition (41).

Food variety is also decreased as people get older, with sensory impairment, financial problems, loneliness and widowhood (47). Data from a cross-sectional survey found that less than two-thirds of older adults have 3 meals on the day of record, with higher intake of carbohydrates, fiber, some micronutrients with lower protein, fat and sodium intake (48). Food choice in older adults depends on the ability to buy food, food preparation, and ingestion.

Meal involves sensations with taste, smell, temperature, texture and chewing sounds. In older adults, the reduction of taste receptor increases taste perception thresholds. Other factors could result in taste dysfunction as well such as chronic diseases, oral status, environmental exposure, zinc deficiency or medications. Taste dysfunction could bring unhealthy eating habit and diet-related diseases (49). The prevalence of older adults with olfactory dysfunction is also high and increasing with age (50). Poor masticatory function in older adults is also found to be the risk of malnutrition (51, 52).

Socioeconomic status also plays a role in older adults' food intake. Poverty is one of the causes of malnutrition in older adults since there are limited resources for buying food, resulting in buying cheap and less nutritious foods (53). Depression is significantly associated with anorexia in older adults and leads to decrease macro- and micro-nutrients intake (54-56).

1.4.1. Food in relation to frailty

Nutrition status is one of the keys in preventing of frailty. Many studies have found the relationship between nutrition status, food intake and the development of frailty (5). The InCHIANTI study, a community-based study in Italy, found that low energy intake was associated with frailty. Similarly, low protein, vitamins D, E, C and folate intake and having low intake of more than three nutrients were also found to be significantly related to frailty in the same study (57).

Protein intake was also found to be associated with frailty in other studies. A cross-sectional study from Japan showed that higher protein intake was related with lower prevalence of frailty among older women, regardless of protein source or the composition of amino acid (58). Rahi et al. found that higher protein intake was associated with lower prevalence of frailty in French community-dwelling older adults (59). However, a study by Bollwein et al. found that not the amount of protein but the distribution of protein intake over the day was associated with frailty (60).

Micronutrients are also related with frailty. Apart from the results from the InCHIANTI study, a study from Japan by Kobayashi et al. showed that 10 micronutrients ((vitamin A, α-carotene, β-carotene, β-carotene equivalent, cryptoxanthin, vitamin B6, vitamin C, vitamin D, α-tocopherol, and folate) were related with a lower prevalence of frailty (61). Similarly, results from longitudinal analysis of Women's Health and Aging Studies pointed out that lower serum carotenoids and α-tocopherol had a significantly increased risk of developing frailty over a 3-years (62).

1.4.2. Eating alone and frailty

Social isolation and loneliness, which are objective and subjective measures, are common problems in older adults, especially those who live alone, have disability, live with poor transportation, low morale, have mental problems and limited social networks (63). These social determinants often lead older adults into eating alone which is a known to increase nutritional risk in adults (64).

Eating with others or commensality has been found to increase food intake, food variety, duration of meal and social interaction (65-67). Recently, eating alone behavior in older adults is known to be associated with various negative health outcomes such as depression, low nutritional status and mortality (68-71). However, to the best of my knowledge, no study has yet explored the relationship between eating alone behavior and frailty.

1.4.3. Dietary pattern and frailty

Since nutrients have complicated interactions and intercorrelations, holistic dietary pattern or whole foods approach has been largely considered in current literature (72). Thus, association between frailty and diet quality or dietary pattern has been recently explored. Bollwein et al. found that a healthy dietary pattern determined by Mediterranean diet score was associated with a lower risk of being frail in German older adults (73). While in Asian populations, Chan et al. studied the diet quality by the Diet Quality Index-International (DQI-

I) score in association with frailty. The results showed the higher DQI-I score was associated with lower risk of frailty at 4 years (74). However, in this study, they could not find the association between Mediterranean diet score and frailty. Frailty was also found to be inversely related with intake of antioxidant both in cross-sectional and longitudinal studies (61, 75).

1.4.4. Dietary pattern and sarcopenia

Although many studies have explored the relationship between food and muscle in aging as a single nutrient approach, only recently, researchers have begun using a whole diet approach to study about the role of food in aging muscle (76). Mainly, Mediterranean dietary pattern was explored in relation to muscle. Systemic reviews show consistent positive association between Mediterranean diet and muscle-related outcomes (77-79). However, there were much variation in Mediterranean diet score and only small number of studies used sarcopenia as an outcome. A cross-sectional study from Iran found that a higher adherence to Mediterranean diet was associated with lower prevalence of sarcopenia (80). Chan et al conducted a longitudinal study in Hong Kong and found no association between a Mediterranean diet and the status of sarcopenia (81). This study is one of a few studies which explored the association between dietary pattern by data driven method and sarcopenia. By data driven method, they found the association between a higher "vegetables-fruits" dietary pattern score and the lower prevalence of sarcopenia in older men (81). The Newcastle 85+ study, which also used the data driven method, shows that a traditional British diet was associated with increased risk of sarcopenia in community-dwelling older adults (82).

1.5. Study rationale

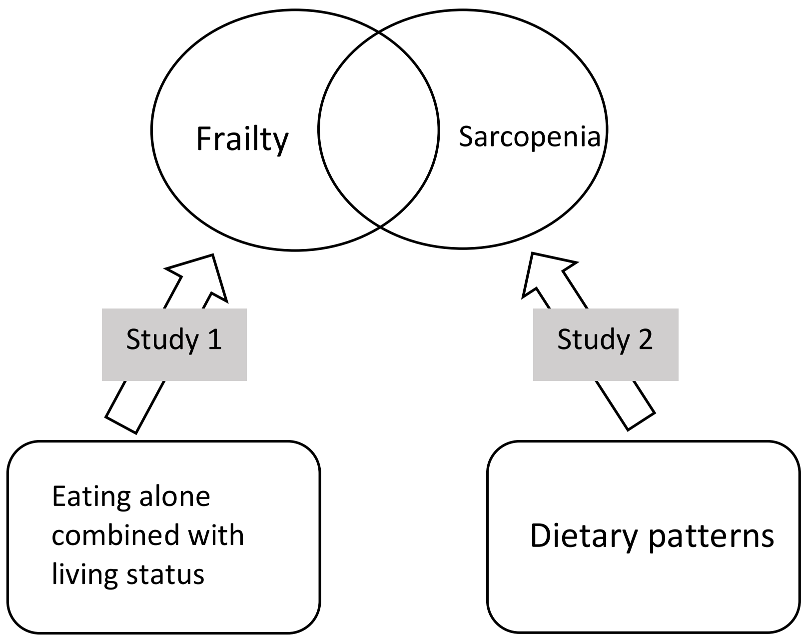
Food is a part of older adults' daily lifestyle and a modifiable environmental factor. It has been an interesting tool for the prevention of frailty especially in community setting (83). Although literature show that food is strongly related with frailty, less attention has been paid to explore the relationship between food behaviors and frailty in older adults. Food intake is also known to be a product of multiple factors. Encouraging appropriate food behaviors should result in better nutritional status and further it could affect psychosocial status of the older adults as well. Therefore, this study focuses on the effects of food, in terms of food behaviors on frailty in older adults.

Eating alone behavior was focused in the first study because having meal is common daily activities, yet eating alone is found to link with various outcomes not only nutritional factor. Social environment during mealtime could be adapted for health promotion or intervention in community-setting. Apart from social environment during mealtime, what to eat was focused in the second study. Traditionally, food is often looked at as a content of individual nutrients. However, the evidence of the effects of whole foods alongside the effects of individual nutrients should be considered (84). Dietary pattern approach includes the totality of a diet and allows for multiple ways to achieve a healthy diet. Therefore, results from researches using dietary pattern approach could be translated easier to dietary recommendations and food behaviors (85)

1.6. Study purpose

In the first study, the aim was to explore the association between eating alone behavior and frailty in community-dwelling older adults. The hypothesis was that eating alone would be associated with higher prevalence of frailty. Moreover, the association was explored further on how eating alone and social interaction during mealtime affects selected domains of frailty. In the second study, the association between food and sarcopenia was explored by dietary pattern approach. This study hypothesized that adherence to specific dietary pattern would be associated with prevalence of sarcopenia. Research design is shown in Figure 3.

Figure 3. Research design



2. Study 1: Association between eating alone combined with living status and frailty

2.1. Introduction

Frailty is known as an important geriatric syndrome. It increases risk of negative health outcomes such as falls, hospitalization, institutionalization, and mortality (86, 87). Prevalence of frailty increases with age, and it affects approximately a quarter to half of people over 85 years (88).

Frailty is strongly associated with diet. A systemic review found that frailty has significant relationships with malnutrition and risk of malnutrition (89). Evidence also shows that low intake of protein and of specific micronutrients are risk factors for frailty (57, 90). Protein is essential for producing muscle mass, linking it to the prevention of sarcopenia, which is the major component in the development of frailty. Nevertheless, dietary behavior and nutrition are also influenced by various other factors, such as motivation, abilities, and environmental opportunities (91).

Eating alone in older adults, which is a dietary behavior related to both physiologic and social factors, has become a social concern recently. The presence of others while eating increases the caloric intake of food and is related to healthier food habits (65, 92). Moreover, eating with others maintains the motivation of older adults to eat and cook, and provides them with opportunities for social interaction and connectedness (93). Cross-sectional analyses and a longitudinal study found that eating alone interacted with living status in its relation to depression and that eating with others acted as a specific type of social activity with extra benefits additional to those of social participation in general (68-70). One study also found gender differences in the association of eating alone and living status with low diet quality and unhealthy weight (obesity or underweight) (94). Men who eat and live alone were reported to have higher risk for mortality than men who do not (71).

However, the relationship of eating alone and living status with frailty has rarely been explored despite the potential for eating alone and living status to affect many domains of frailty, such as nutrition, socialization, and mood. The results might pave the way for future studies to yield the new practical way for prevention and treatment of frailty. Therefore, this study aimed to examine the relationship of eating alone behavior and living status with frailty in community-dwelling older adults.

2.2. Methods

2.2.1. Design and participants

This is a cross-sectional study. The baseline data from the Kashiwa study was used. Kashiwa study is a cohort study started in 2012 in the city of Kashiwa, Chiba prefecture, Japan. The study was designed to capture biological, psychosocial and functional changes with aging in a community-based setting. A total of 12000 community-dwelling older adults aged 65 years and over who were non-eligible for long-term care were randomly selected from resident register. They were asked by mail to participate in the study and 2044 older adults agreed to participate. The baseline examinations were done from September to November 2012 at welfare centers and community centers near the participants' residential area. Data collection was done by multidisciplinary team including physicians, nurses, physical therapists, dentists and nutritionists. Exclusion criteria were those who had missing items of data or impaired cognitive function [Mini-Mental State Examination (MMSE) score ≤ 18].

2.2.2. Eating and living status

Eating and living status at present condition were assessed by self-reported questionnaire with the following questions: "Do you eat your meals with anyone else, at least once a day: yes or no?" and "Do you live with your family: yes or no?" Eating and living status in this study’s participants were found to be statistically associated. The preliminary analysis in this study showed that eating status associated differently with frailty depends on living alone or not, conforming with the results from previous literature (69, 71). Hence, eating and living status were crossed to make 4 categories: “eating and living with others” (reference), “eating with others yet living alone,” “eating alone yet living with others,” and “eating and living alone.”

2.2.3. Frailty

Frailty was assessed using the Kihon Checklist (KCL), a Japanese frailty index, which constitutes a self-reported comprehensive health questionnaire. The KCL includes 25 items regarding these 7 domains: instrumental activities of daily living (IADL), physical strength, nutrition, eating, socialization, memory, and mood. This checklist was found to be closely correlated with frailty as defined by the Cardiovascular Health Study criteria; scores of ≥8 were defined as frail (95).Cut-off points for each domain were adopted from a previous systematic review (28),and scores below the cut-off point suggested low or at risk status in that domain (see Appendix 1,2).

2.2.4. Other variables

Sociodemographic variables and social engagement

Participants’ age and years of education were obtained with a standardized self-report questionnaire and then confirmed the data with face-to-face interviews. The data was added to the analysis as continuous variables. The Lubben Social Network Scale-6 was used to measure social ties with friends and family (96).

Medical histories

Number of chronic diseases and history of cerebrovascular disease, hypertension, diabetes, osteoporosis, chronic kidney disease, heart disease, and/or cancer were assessed during interviews by nurses.

Function and mental health

Trained staff evaluated cognitive function using the MMSE, and the score was added to the analysis as a continuous variable. The 15-item Geriatric Depression Scale was used to evaluate depressive symptoms. Having trouble with shopping was evaluated by self-report, with the question "Do you have trouble with shopping: yes or no?"

Nutritional, dietary and oral health status

Weight and height were measured in order to calculate body mass index (BMI). Mini Nutritional Assessment-Short From (MNA-SF) assessed nutritional status, using self-report questionnaire, BMI, and MMSE data (97). Food quality was evaluated by number of meals per day and 10-item food diversity questionnaire for frequency of meat or fish and vegetable or fruit intake (98). Food enjoyment and food preparation were assessed by self-report questionnaire, with the questions "Do you enjoy your meals: yes or no?" and "Do you prepare meals by yourself: yes or no?" The number of functional teeth were checked by dental hygienists. All the assessments including anthropometric, nutritional status, and eating and living status assessments were performed in 2012.

2.2.5. Statistical analysis

Analyses were stratified by gender because the results of preliminary analysis and previous literature showed different relationship of eating and living status with health outcomes between men and women (70, 71, 94). Unpaired student's t-test, Mann Whitney test and Pearson's chi-squared test were used to compare baseline characteristics between participants with and without frailty. Binary logistic regression analysis was performed with frailty status as the dependent variable. Model 1 was a non-adjusted model. In model 2, the adjusted variables were age, years of education, chronic diseases, MMSE, and number of functional teeth. Multicollinearity among the independent variables in the model was checked using the variable inflation factor. No multicollinearity was found. To determine further the causes of the relationship of eating and living status with frailty, binary logistic regression analysis was also performed, using each domain from the Kihon Checklist (IADL, physical strength, nutrition, eating, socialization, memory, and mood domain). The characteristics of each eating/living status group were also compared, by chi-squared test for categorical variables and ANOVA test for continuous variables, with multiple comparisons. IBM SPSS statistics v 22 for Windows (IBM Japan, Tokyo) was used to perform statistical analysis; *P* value of <.05 was considered statistically significant.

2.2.6. Ethical considerations

The "Kashiwa study" was approved by the Ethics Committee of the university (#12-8). Data received for analysis had been de-identified, including only ID numbers. The participants' names and confidential information were excluded to ensure the protection of personal information. All participants provided written informed consent.

2.3. Results

2.3.1. Characteristics of participants

From the baseline of 2,044 participants, 130 participants were excluded based on missing data or low MMSE score, as described above, resulting in a final number of 1,914 participants. Table 1 shows the characteristics among included and excluded participants. Excluded participants were older, had less years of education, ate alone more, had more chronic diseases and higher depressive score. Among included participants, 49.8% were male and whose overall mean age was 72.9 years. Among men, the "eating and living alone" group accounted for 4.5%, the "eating alone despite living with others" group for 6.7%, "eating with others yet living alone" for 1.3%, and "eating and living with others" for 87.5%. Among women, the respective percentages were 13.1%, 5.3%, 2.8%, and 78.8%. Of all the participants, 56 (5.9%) of men and 112 (11.7%) of women were frail. Table 2 presents the characteristics of participants with and without frailty. In both genders, compared to participants without frailty, participants who were frail ate alone more, had more chronic diseases, had higher depressive score, and ate less meat/fish. In women, frail participants were also older and had fewer years of education and lower cognitive function and oral status.

2.3.2. Association between eating and living status and frailty and its domains

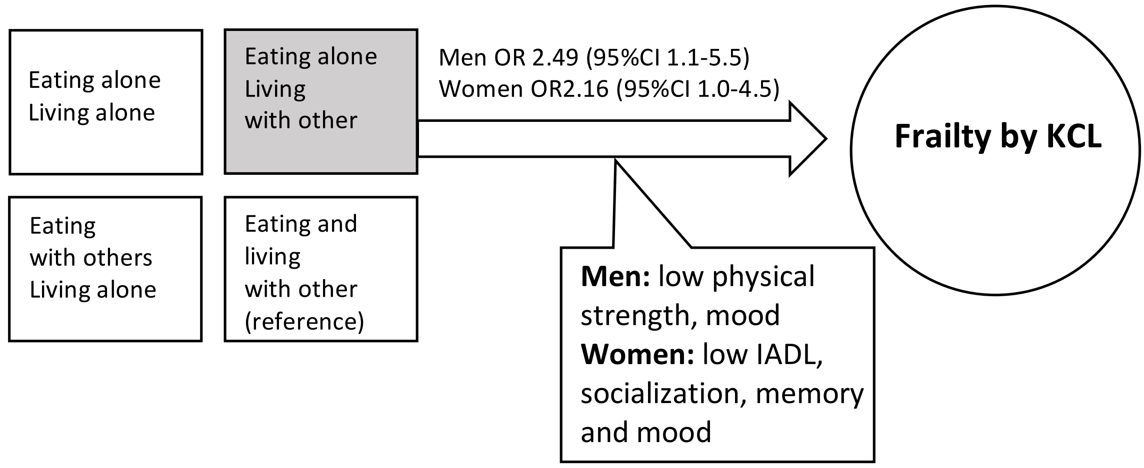
Binary logistic regression models were used to analyze associations of eating and living status with frailty (Table 3). Men who ate alone despite living with others were more likely to be frail after adjusting for age, years of education, chronic diseases, cognitive function, and number of functional teeth. For women, participants who ate alone yet lived with others or who ate and lived alone were more likely to be frail in the unadjusted model, but after adjustment, the association only remained for women who ate alone yet lived with others.

Table 4 shows the associations of eating and living status with frailty domains after adjusting for age, years of education, and number of chronic diseases. In men, eating and living status were significantly associated with physical and mood domains. Men who ate and lived alone were more likely to have low physical strength. Men who ate alone yet lived with others or who ate and lived alone showed higher frequency of depressive risk. On the other hand, women who ate alone despite living with others were more likely to be impaired in IADL, socialization, memory, and mood domains.

2.3.3. Gender differences in characteristics based on eating and living status

To further examine the mechanism of the association of eating and living status with frailty, the characteristics of each eating and living status group were compared, as seen in Table 5 and 6. In both genders, the "eating alone yet living with others" group was older, had fewer years of education, was more likely to live with their children and not their spouse, and had low food enjoyment compared to older adults who ate and lived with others. Furthermore, men in this group ate less meat/fish and vegetables/fruits than men who ate and lived with others. In women, the "eating alone yet living with others" group ate less meat/fish, reported having trouble with shopping more often, and had more family members than the "eating and living with others" group. The results from Study 1 were summarized in Figure 4.

Figure 4. Summary of Study 1 results



2.4. Discussion and conclusion

To my knowledge, this is the first study that examined the relationship of eating alone behavior and living status with frailty in community-dwelling older adults. This study found that eating alone despite living with others was associated with higher prevalence of frailty both in men and in women. Regarding relationships with each domain of frailty, this study also newly found different associations between men and women. In men, eating and living status were associated with impaired physical strength and mood domain, whereas in women these statuses were associated with impairment in IADL, socialization, memory, and mood domain.

The association was found between eating alone despite living with others and frailty in this study. Previous literature supports it, in which older people in "eating alone despite living with others" group were particularly vulnerable, reflected in associations with low nutritional status, depression, and mortality (69, 71, 94). Family meal time provides a sense of belonging and mutual aid for older adults with extra benefits additional to general social participation (69, 99). The "eating alone yet living with others" group missed these opportunities. In addition, eating alone while living with family could be the consequence of many situations: lack of good relationships among family members especially in different generations, different kind of meal or life style, or living in the same house but separate unit.

From our study, depression domain could be a major cause of frailty in older adults of both genders "eating alone yet living with others." Later-life depression and frailty share several pathophysiologic mechanisms: subclinical cerebrovascular disease, chronic inflammation, and hypothalamic-pituitary-adrenal axis dysregulation of hormones (100). Longitudinal studies have found increased risk of frailty in older adults with depressive symptomatology (101). Apart from depression, loneliness—the subjective experience of a shortfall in one's social resources—might also play a role in developing frailty (102).

The sex difference in the associations with frailty components might be the effect of gender roles and psychosocial factors. In men, the results of low physical strength domain might be from low consumption of food and energy as seen in low frequency of meal and vegetables/fruits consumption in men who ate and lived alone since they tend to lack cooking skill and follow poor dietary behavior. Living alone also affects mood in men more because their previous roles such as management and decision-making authority are lost when living alone (103). In women, the mechanisms involved in IADL, memory, and socialization domains might be due to "lifespace constriction" which is more likely to happen in women. Women's social role involves taking care of their family, especially providing high-quality meals (104). As a result, women who eat alone yet live with family may experience the loss of this social role, and feel less inspiration to cook or to go out and shop for food.Furthermore, the results from this study showed that this group reported having more trouble shopping than the other groups of women. Therefore, I suspect that they do not get enough support (in this realm or in general) from their family and community. A longitudinal study reported that women who leave their neighborhood less frequently have higher risk of frailty (22).

A significant relationship was not found among the nutrition domain with eating and living status because the nutrition domain in the KCL focuses on questions about malnutrition, of which frequency was low in the older adults in this study. However, that the "eating alone yet living with others" group was found to consume meat/fish and vegetables/fruits less frequently than the other groups; protein and specific vitamins have been found to be nutrition components related to mechanisms of frailty (90).Positive social feedback from peers increases expected liking and positive attitudes towards a food (105). Older adults who ate alone despite living with others lacked positive emotional experience with food, and thus did not try to meet social norms around eating (106).

It is important to note that no association was found with frailty in the "eating and living alone" group or the "eating together yet living alone" group. These two groups of older adults might be able to cope with stress by adaptation over time, providing a sense of control which reduces the effect of stress and is associated with better health outcomes and desired behavioral changes (107).

Some may argue that eating alone itself might be one of the definition of social frailty. However, the definition of social frailty is not yet well established (108). Moreover, most of previous literature did not include eating alone as the criteria of social frailty (109-111). Eating alone also has wider effect more than social dimension.

The following limitations need to be addressed in this study. The cross-sectional design was used in this study because of the high number of participants at baseline and the low follow-up rate in Kashiwa study. However, this makes it difficult to claim causal inferences. For example, frailty might restrain older adults from having meals with others; nevertheless, previous studies have found that eating alone behavior leads to depression and underweight, which are strongly related to frailty. Thus, it might be likely that eating alone behavior could have a causal effect on frailty, as well as vice versa. Second, only a single item on eating alone was used, and thus the effect could not be estimated of frequency of eating alone, who the eating partner was, or interaction during mealtime. Third, living with family but eating alone could be the consequence of many situations which might confound the relationship between eating behavior and frailty. Fourth, only a low frequency of older adults who ate with others but lived alone was found, leaving us unable to calculate some relationships. Lastly, participants in this study were healthy older adults who could go to the community or welfare center. Excluded participants were also older and had more risks for frailty. Hence, the included participants might not represent vulnerable population who are prone to frailty.

In conclusion, this study found that "eating alone yet living with others" is associated with frailty and its domains in community-dwelling older adults. Moreover, pathways of this association were different among men and women. Eating and living status were associated with lower physical strength and mood in men, whereas in women these statuses were associated with lower scores for IADL, socialization, memory, and mood.

3. Study 2: Association between dietary patterns and sarcopenia

3.1. Introduction

In this study, the association between food behaviors was further explored in terms of food choices and sarcopenia. Sarcopenia which overlaps with physical frailty was used as the outcome to focus more on the association of food and muscle changes.

Sarcopenia, an age-related decline of muscle mass and function, is a major health problem in older adults. Based on consensuses developed by International, European, and Asian working groups on sarcopenia, a systemic review reported the prevalence of sarcopenia among community-dwelling older adults to be as high as 10% in both men and women (112). Sarcopenia can lead to mobility disorders, increased risk of falls, frailty, disabilities, poor quality of life, and increased mortality risk (43, 113-115). Therefore, the development of effective prevention and treatment measures for sarcopenia is essential to ensure the health of older adults.

Muscle mass and strength decrease at different rates among older populations, suggesting the possible effects of modifiable factors such as diet and lifestyle (116). A large body of evidence shows that efficient protein intake is crucial to maintain muscle mass, strength, and physical performance (117-119). Intervention studies have reported a positive effect of vitamin D supplementation on muscle fibers (120). Moreover, dietary fat composition, antioxidants, and minerals, such as magnesium, are also reported to affect muscle mass and function (117, 121).

However, recently, holistic dietary pattern approach has been largely considered because a single nutrient approach is insufficient to examine complicated interactions and intercorrelations among nutrients (72). Dietary pattern can be defined as the quantities, proportions, and combination of various foods and drinks habitually consumed in diets (122).

There are two main research methods to identify dietary patterns— dietary indices and data-driven statistical methods. The former uses a priori–defined indices to determine a specific food intake pattern, usually on the basis of dietary guidelines. The latter involves an a posteriori method using cluster analysis, factor analysis, and reduced rank regression to derive major patterns from the data (122).

Limited studies have explored the relationship between dietary patterns and sarcopenia. A cross-sectional study conducted in Iran found that adherence to the Mediterranean diet was associated with lower prevalence of sarcopenia (80). A study conducted in Hong Kong examined the association between dietary patterns using both dietary indices and factor analysis methods and reported that an a priori dietary pattern, the Diet Quality Index-International (DQI-I), and a posteriori dietary patterns, namely "vegetables-fruits" and "snack-drinks-milk products," were associated with lower odds of sarcopenia in men (81). However, this study could not identify an association between dietary patterns and sarcopenia in women or an association between the Mediterranean dietary pattern and sarcopenia in both genders. A study by Granic et al. examined the effect of dietary patterns on the risk of sarcopenia among older adults aged over 85 years in the UK (82). They reported that dietary pattern, which involved a high consumption of butter, red meat, gravy, and potato, was associated with an increased risk of sarcopenia despite good protein intake.

Japan has the highest proportion of older population in the world (123). The prevalence of sarcopenia in Japanese older adults is 9.6% in men and 7.7% in women, according to a study reported in 2015 (124). However, the relationship between dietary patterns and sarcopenia has not been sufficiently investigated among the Japanese older population. The traditional Japanese diet (*Washoku*) is considered to be healthy, and it is associated with a lower risk of dementia, cardiovascular diseases, and all-cause mortality (125, 126). Given that diets vary by region and culture, a dietary pattern related to those of East Asian cultures might be more effective for Japanese population than a Mediterranean dietary pattern.

In this study, the aim is to identify the major dietary patterns among Japanese community-dwelling older adults using principal component analysis. Then, based on these dietary patterns and the a priori Japanese diet score, the association between dietary patterns and sarcopenia was explored.

3.2. Methods

3.2.1. Design and participants

This is a cross-sectional study using the data from the Kashiwa study which is a cohort study started in 2012 in the city of Kashiwa in Chiba prefecture, Japan. The study details are in the previous section. Briefly, community-dwelling older adults aged 65 years and over, who were not eligible for long-term care, were randomly selected from resident register, and their participation was requested by mail. Data were collected at welfare and community centers by multidisciplinary team. The current study is a cross-sectional analysis of the Kashiwa study data from wave 3, which was carried out in 2014. The sample comprised 1241 older adults, and 646 (52%) were male. Exclusion criteria were participants with incomplete sociodemographic or dietary data and participants with extreme energy intake.

3.2.2. Dietary assessment

Dietary intake was assessed using the brief self-administered diet history questionnaire (BDHQ) which has been validated (127). The BDHQ is a fixed portion questionnaire that assesses the consumption frequency of selected foods in the preceding month to estimate the dietary intake of 58 commonly consumed food and beverage items. The crude intake of energy and nutrients was calculated based on the food composition list in the Standard Tables of Food Composition in Japan (128). Residual method by regression model was used to obtain energy-adjusted values of food and nutrients.

3.2.3. Dietary pattern scores

To identify a posterior dietary patterns, a principal component analysis with varimax rotation was performed using 47 food items from the BDHQ (excluding alcohol items, cooking methods, and dietary behaviors). The number of components was determined by eigenvalue > 1.5, scree plot, and factor interpretability (129). Dietary pattern scores were calculated by summing daily intake of food items weighted by their factor loadings. Food item with a positive loading indicates a positive association with dietary pattern and the vice versa for a negative loading. High dietary pattern scores indicate better adherence to that dietary pattern. The patterns were confirmed by running the analysis in random half sample.

To obtain the Japanese diet score, a score based on the existing literature was used along with the results of principal component analysis (125, 130, 131). It includes seven food groups: beans and bean products, fish, vegetables, pickles, mushroom, seaweeds, and fruits. One point would be given if consumption of any food item in the food group was more than 4 times/week. A higher score indicates higher adherence to the Japanese diet. The Japanese diet score was classified into three groups according to the score distribution (0–2, 3–4, 5–7 for men and 0–4, 5, 6–7 for women).

3.2.4. Sarcopenia

Criteria recommended by the Asian Working Group for Sarcopenia was used for measuring sarcopenia. It defined sarcopenia as low muscle mass with low muscle strength or low physical performance (131). Muscle mass was measured by bioelectrical impedance analysis using the InBody430 (InBody Japan, Tokyo, Japan). Low muscle mass was defined as appendicular skeletal muscle mass index of <7.0 kg/m^2 for men and <5.7 kg/m^2 for women. Muscle strength was assessed by hand grip test with a grip dynamometer (Grip D, Takei Scientific Instruments, Niigata, Japan). The test was assessed twice and the better score would be used in the analysis. Low muscle strength was defined as <26 kg for men and <18 kg for women. Gait speed was used as a test for physical performance. Participants were asked to walk 11 m in a straight line, and at the middle 5-m distance (between 3 m and 8 m from the start line) the speed would be recorded. Low gait speed was defined as <0.8 m/s for both genders.

3.2.5. Other variables

A standardized self-report questionnaire was used to obtain participants' sociodemographic information including age, sex, financial status, living alone status. Trained nurses interviewed for medical histories and current medication. BMI was calculated as weight (kilogram) divided by height (metre^2). Level of physical activities was assessed by Global Physical Activity Questionnaire (GPAQ). Trained staff evaluated cognitive function using the Mini-Mental State Examination (MMSE). The 15-item Geriatric Depression Scale (GDS) was used to evaluate depressive symptoms.

3.2.6. Statistical analysis

Statistical analyses were performed using IBM SPSS statistics v 22 for Windows (IBM Japan, Tokyo). Analyses were stratified by gender because preliminary analysis showed different relationship of dietary patterns with sarcopenia between genders which is also in line with previous literature. Unpaired student's t-test, Mann Whitney test and Chi-squared test were used to compare baseline characteristics between participants with and without sarcopenia. Binary logistic regression analysis was performed with sarcopenia status as the dependent variable. Model 1 was adjusted for age and Model 2 was further adjusted for economic circumstance, living alone, BMI, energy intake, multimorbidity and physical activity. Multicollinearity among the independent variables was checked in the model using the variable inflation factor. No multicollinearity was found among the independent variables.

3.2.7. Ethical considerations

The "Kashiwa study" was approved by the Ethics Committee of the university (#12-8). All participants provided written informed consent.

.3.3. Results

3.3.1. Derived dietary patterns and characteristics of participants

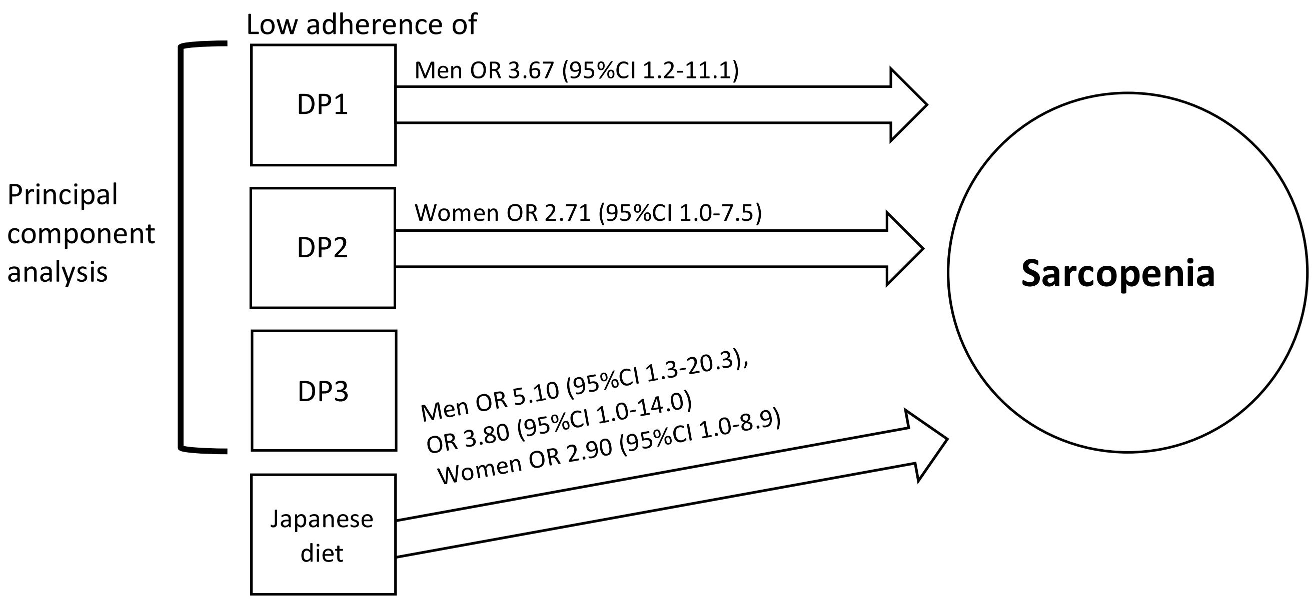
There was a total of 1,241 participants, of which 52.1% were male. Fourty-eight participants were excluded due to the exclusion criteria. Participants' mean age was 74.6 years. According to the AWGS criteria, 5.1% of the participants had sarcopenia. Table 7 shows the three dietary patterns identified from the principal component analysis along with factor loading for the food groups. The first two dietary patterns were characteristic of the traditional Japanese diet comprising staple foods, soups, and various side dishes. Dietary pattern 1 (DP1) was defined as a dietary pattern with factor loadings, >0.3 for fish, tofu, vegetables, and fruits. This dietary pattern is similar to the Japanese side dishes. Dietary pattern 2 (DP2) was a dietary pattern with high factor loadings for fish, rice and miso soup, which are the components of main Japanese dishes. Dietary pattern 3 (DP3) was a dietary pattern with a high factor loading for noodle food groups comprising buckwheat noodles, Japanese wheat noodles, instant noodles and Chinese noodles, and spaghetti and macaroni.

Table 8 shows the scores of all dietary patterns, including the Japanese diet scores of both men and women. In the bivariate analysis by Mann Whitney test, women scored significantly higher for DP1 and Japanese diet than did men. Table 9 shows the characteristics of the participants by sarcopenia status. Among both genders, participants with sarcopenia were older, had a lower level of physical activities, and had a lower BMI. Men with sarcopenia had higher GDS score, while women with sarcopenia had lower MMSE score. Men with sarcopenia had lower DP1 score than men without sarcopenia. Women with sarcopenia had a lower DP2 score than women without sarcopenia. (Table 10)

3.3.2 Association between dietary patterns and sarcopenia

The results of the logistic regression (Table 11) shows that men at the lowest tertile of DP1 score (Japanese side dishes) had a higher likelihood of being sarcopenic in Model 1 compared to men at the highest tertile. This relationship still existed after adjustment in Model 2 (Adjusted odds ratio [OR] 3.67, 95% confidence interval [CI] 1.20-11.2). For DP2 (Japanese main dishes), there was a weak relationship between lower scores and a higher likelihood of sarcopenia among female participants. Furthermore, in both men and women, lower adherence to the Japanese dietary pattern was associated with the prevalence of sarcopenia. A score between 0 and 4 was associated with a higher likelihood of sarcopenia among men compared to those with a score of 5–7 (OR 5.10, 95%CI 1.27–20.3 for scores 0–2; OR 3.80, 95%CI 1.04–14.0 for scores 3–4). Meanwhile, women with a score of 0–4 had a higher prevalence of sarcopenia than women with a score of 6–7 (OR 2.90, 95%CI 0.9–8.88), although this was not statistically significant. No association was found between DP3 and sarcopenia. The results from Study 2 were summarized in Figure 5.

Figure 5. Summary of Study 2 results



3.4. Discussion and conclusion

In this study, three dietary patterns were identified from a principal component analysis: DP1 (fish-tofu-vegetables-fruits: Japanese side dishes), DP2 (rice-fish- miso soup: Japanese main dishes), DP3 (noodles). The results from this study showed that adherence to DP1 in men, DP2 in women, and the Japanese dietary pattern in both genders was inversely associated with sarcopenia.

DP1 was found as a dietary pattern with high consumption of fish, tofu, vegetables and fruits or Japanese side dishes in this study. This dietary pattern is similar to the patterns from previous studies which employed factor analysis to derive the dietary patterns in Japanese population. The vegetable dietary pattern in the JACC study and the Japanese dietary pattern in the Ohsaki study also had high factor loadings of fresh fish, vegetables, fungi, potatoes, seaweed, tofu, and fruits groups, although the BDHQ was used for dietary assessment in this study (126, 130). However, DP1 had low factor loading for green tea, sweets, rice, and miso soup, unlike the Japanese dietary pattern in the Ohsaki study. The other two a posteriori patterns in this study were not identified in previous studies.

The finding from this study showed that adherence to a healthy dietary pattern with high food variety was associated with low risk of sarcopenia. This finding is in line with that of the previous studies (80, 81, 132). Hashemi observed that a higher score of the Mediterranean dietary pattern, characterized by the consumption of olive oil, fruits, vegetables, fish, and nuts, is associated with lower odds of sarcopenia (80). A study conducted in Hong Kong found that adherence to the "vegetables-fruits" dietary pattern is associated with a lower likelihood of sarcopenia among men (81). In Isanejad's study, adherence to the Baltic Sea diet and Mediterranean diet was associated with higher physical performance and muscle function (132).

The components of DP1 "Japanese side dishes" derived from the principal component analysis and a priori–defined Japanese dietary pattern were similar with each other. The relationship between these two dietary patterns and sarcopenia might arise from various nutrient components. These dietary patterns were related to a high consumption of high-quality protein from both animal- and plant-based sources (Appendix 4). Consumption of protein, especially from animal sources, has been known to play a major role in building and preserving muscle mass (119, 133). Animal-based protein is more effective than plant-based protein in muscle anabolic processes since it has higher protein digestibility corrected amino acid (PDCAA) score (134). However, animal-based foods are high in saturated fat, which is associated with a high risk in cardiovascular diseases and reduced bone health.

DP1 and Japanese diet score was found to be related with both high fish and soybean consumption. Fish is a good source of animal protein and has low saturated fatty acid levels. Fish is also high in omega-3 fatty acids and vitamin D. In an observational study, omega-3 fatty acids were related to protection against disabilities (135), and in an intervention study, they were related to muscle mass and function (136). Many observational studies found that vitamin D level is related to physical performance in older adults (137-139). Soybean provides plant-based protein, which is reported to have the same PDCAA score as animal-based protein. Supplementation of soy protein is related to increased muscle function (140, 141). Moreover, protein blend, which combines animal- and plant-based protein, might enhance the postprandial muscle protein synthesis response (142).

Further, high consumption of vegetables and fruits in these dietary patterns (Appendix 5) could result in lower odds of sarcopenia as seen in a Korean study (143). This might be attributable to high levels of antioxidants and alkalosis. Moreover, cross-sectional and longitudinal studies show that higher antioxidant consumption, including vitamins C, E, and carotenoids, is related to physical function and prevention of loss of muscle mass (117, 144). In addition, mild metabolic acidosis is associated with skeletal muscle loss. A longitudinal study reported an alkaline diet comprising fruits and vegetables is positively related to muscle mass and improvement in lean body mass (145).

The main contents of DP1 and Japanese diet score in this study were soybeans/soybean-derived products, seafood, and vegetables. These contents were similar to that of the traditional Japanese diet. The traditional Japanese diet is listed in UNESCO's list of Intangible Cultural Heritage in 2013. It is well-known for a variety of foods and is characterized by abundant vegetables, small portions, and several cooking methods (146). Although the contents of the traditional Japanese diet are varied among studies, the main food groups are soybeans/soybean-derived products, seafood, and vegetables (following by rice and miso soup) (147). Other components, which are unique to the traditional Japanese diet, are also worth mentioning. Mushroom is a rich source of antioxidants, and seaweed is a rich source of minerals. Although the problem of high salt intake, especially from pickles, in the Japanese diet might be a concern, a study found that the Japanese diet score including pickles is negatively related to the risk of cardiovascular disease mortality (125). This might be due to the low sodium-potassium ratio as a result of a high potassium level from vegetables and fruits in the Japanese diet.

In this study, gender differences were detected in the relationship between dietary patterns and the prevalence of sarcopenia. No association was found between DP1 and the prevalence of sarcopenia in women. This might be due to the differences in eating habits between male and female participants. Women had a higher DP1 score than men suggesting that they already consumed more fish, tofu, vegetables, and fruits habitually; thus, there was no difference in the relationship between DP1 and sarcopenia. Additionally, this might also be due to the negative loading of rice in this pattern, which is also related to the lower likelihood of sarcopenia in women with higher adherence to DP2.

Associations were also examined between dietary patterns and each domain of sarcopenia: muscle mass, muscle strength, and physical performance. The adherence to the Japanese diet was found to be associated with higher muscle strength (Appendix 6).

This study has some limitations. First, the cross-sectional design of this study precludes causal inferences. Non-sarcopenic older adults might be able to cook and shop for food more, resulting in adherence to diet with high variety of food or Japanese diet. However, previous literature show longitudinal effect of food components including in our dietary patterns on maintaining muscle mass and function, so it might be likely that adherence to dietary patterns could prevent sarcopenia. Second, dietary assessment in this study relied on the memory of participants, and thus, recall bias is possible. Third, the prevalence of sarcopenia in the present study was lower than that in previous studies (80, 81). The participants in this study were older adults who were not eligible for long term care so this might not represent all the vulnerable population for frailty. Fourth, the dietary pattern and the Japanese diet score in this study might not be applicable to other regions, owing to differences in the food culture. Fifth, comparison between Japanese dietary pattern and western dietary patterns such as Mediterranean dietary pattern was not done, hence the difference of the effects could not be confirmed. However, the strengths of this study include the application of both dietary indices and data-driven statistical methods to derive dietary patterns, as well as the use of Asian-specific definition for sarcopenia. To my knowledge, this study is the first to explore the relationship between dietary pattern and sarcopenia among Japanese community-dwelling older adults.

In conclusion, this study found three dietary patterns from the participants' dietary history: DP1 (Japanese side dishes), DP2 (Japanese main dishes) and DP3 (noodles). Japanese diet score was also used from review of previous literature. The results showed that adherence to the traditional Japanese diet, which involves high consumption of fish, soybean products, vegetables, and fruits, was associated with low prevalence of sarcopenia among older Japanese adults.

4. Integrated conclusions

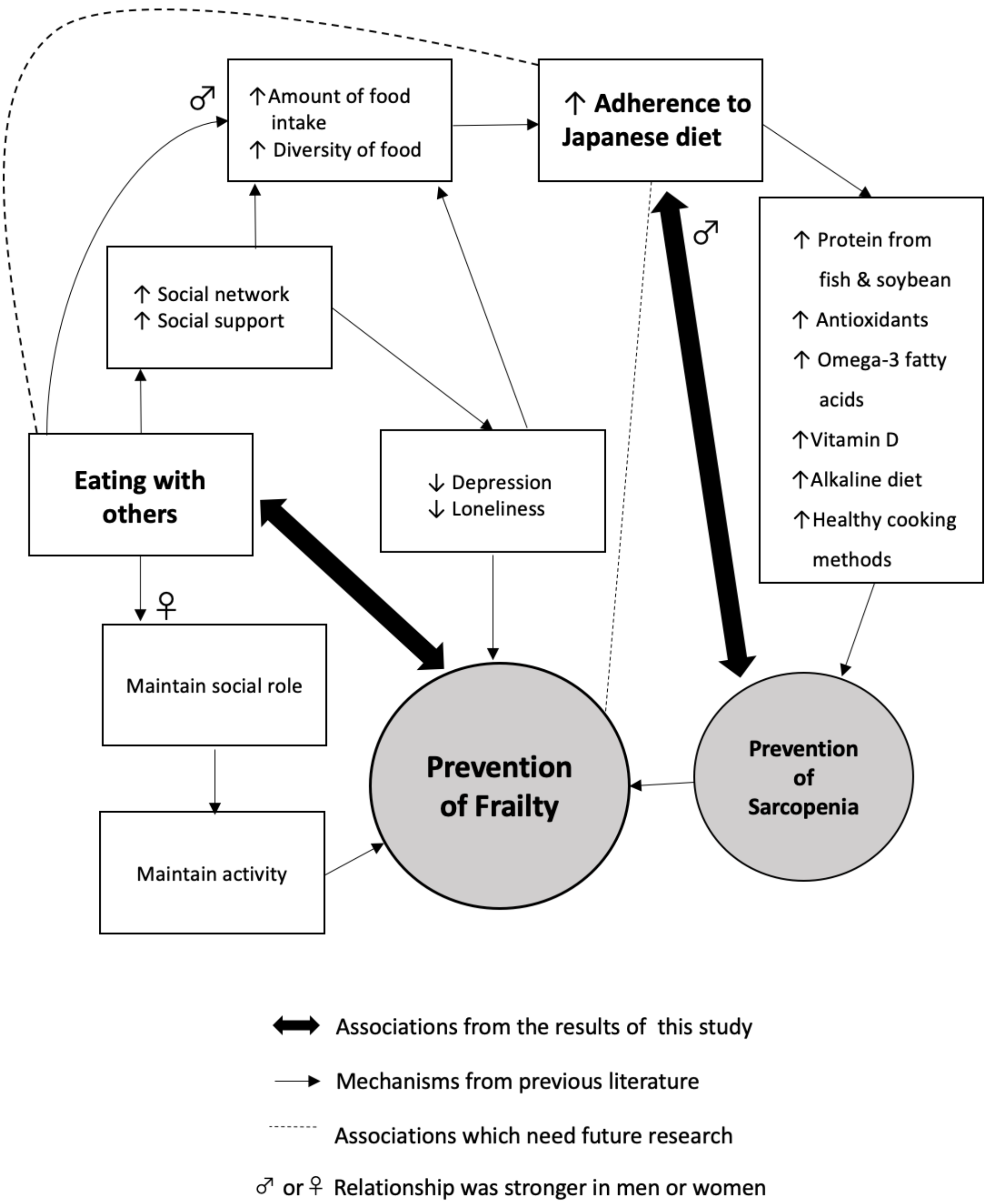
This is the first study aimed to explore the association between food behaviors and frailty or sarcopenia in Japanese community-dwelling older adults, focusing on eating alone behaviors and dietary patterns.

This study newly highlighted the role of food behaviors in association with frailty and sarcopenia. Although there are many recommendations about nutrients from food for frailty prevention and intervention, other dimensions of food such as eating with others and whole of foods aspect could affect selected domains of frailty as well. Diet with high consumption of fish, soybean products, vegetables, and fruits was associated with low prevalence of sarcopenia, one of the main contributing factors for frailty, or some might call it physical frailty. While meal environment, a meal with others, was associated with frailty in terms of psycho-social, activity and also physical dimension. Combining the results from these two studies should lead to multifaceted frailty prevention, resulting in promotion of healthy aging in a comprehensive way. A simple, fundamental intervention approach might be set up in community setting, depending on older adults' gender and high-risk domains.

Longitudinal and interventional studies should be conducted in the future to gain a better understanding of the effects of commensality and Japanese traditional diet to prevent frailty. To give nutrition support in older adults in order to prevent frailty, one needs to think beyond individual nutrients. There might be a role for high intake of food with the components of Japanese traditional diet. Hence, care providers might give information about better food choices, cooking methods and support for food shopping for older adults and family to increase adherence of this diet. Older adults who have poor oral status which might interfere with chewing hard food such as vegetables or fruits should be checked and referred to dental care. To apply this dietary pattern approach to older adults in other countries, food culture should be explored and Japanese diet needs to be adapted to fit with non-Japanese population.

Moreover, support for social interaction during mealtime should be given whether the person lives alone or not. Services to support commensality should be provided such as food delivery with meal companion or older people' club/cafeteria where people could eat with others. Family members should be given information about the benefit of eating together and family meal environment should be encouraged. Other food behaviors such as food preparation, shopping for food or eating place might need to be explored as well. Figure 6 summarized the proposed mechanisms from this study.

Figure 6. Proposed mechanisms from this study



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7. Tables

Table 1 Characteristics of participants comparing between included and excluded participants

Variables	Included participants (n= 1914)	Excluded participants (n=130)	*P* value
	Mean (SD) or n(%)		
Age (years)	72.9 (5.5)	74.8 (6.6)	<0.001
Education (years)	12.7 (2.8)	12.0 (3.0)	0.003
Living alone	208 (10.9)	18 (13.8)	0.310
Eating and living with others	1591 (83.1)	95 (73.1)	0.007
Eating with others yet living alone	39 (2.0)	4 (3.1)	
Eating alone yet living with others	115 (6.0)	17 (13.1)	
Eating and living alone	169 (8.8)	14 (10.8)	
Number of chronic diseases (≥2 diseases)	831 (43.4)	64 (54.2)	0.022
GDS score	2.6 (2.9)	3.5 (3.3)	0.001
Number of functional teeth	27.1 (2.5)	26.8 (3.1)	0.114

GDS, Geriatric Depression Scale

Table 2. Characteristics of participants*

Variables	Men			Women		
	Non-frail (n= 897)	Frail (n=56)	*P* value	Non-frail (n=849)	Frail (n=112)	*P* value
	Mean (SD) or n(%)			Mean (SD) or n(%)		
Sociodemographic variables						
Age (years)	72.9 (5.5)	76.4 (6.0)	0.200	72.3 (5.2)	76.0 (6.4)	0.006
Education (years)	13.7 (2.9)	12.3 (3.1)	0.881	11.9 (2.2)	11.1 (2.5)	0.001
Social engagement						
Living alone	51 (5.7)	4 (7.1)	0.874	125 (14.7)	28 (25.0)	0.008
Eating and living with others	792 (88.4)	42 (75.0)	0.001	685 (80.8)	72 (64.4)	0.001
Eating with others yet living alone	12 (1.3)	0 (0.0)		21 (2.4)	6 (5.3)	
Eating alone yet living with others	54 (6.0)	10 (17.9)		39 (4.6)	12 (10.7)	
Eating and living alone	39 (4.3)	4(7.1)		104 (12.2)	22 (19.6)	
Social ties with family	8.0 (3.2)	7.5 (3.3)	0.719	8.2 (3.1)	8.2 (3.5)	0.062
Social ties with friends	7.9 (3.6)	8.3 (3.7)	0.998	8.2 (3.6)	8.6 (3.8)	0.619
Medical histories						
Hypertension	415 (46.3)	28 (50.0)	0.685	328 (38.6)	55 (49.1)	0.043
Cerebrovascular diseases	59 (6.6)	10 (17.9)	0.004	33 (3.9)	13 (11.6)	0.001
Diabetes	132 (14.7)	14 (25.0)	0.060	70 (8.2)	12 (10.7)	0.484
Osteoporosis	15 (1.7)	4 (7.1)	0.004	157 (18.5)	38 (33.9)	<0.001
Heart diseases	181 (20.2)	21 (37.5)	0.004	104 (12.2)	26 (23.2)	0.002
Chronic kidney disease	7 (0.8)	1 (1.8)	0.424	4 (0.5)	1 (0.9)	0.560
Cancer	165 (18.4)	16 (28.6)	0.060	96 (11.3)	15 (13.4)	0.516
Number of chronic diseases (≥2 diseases)	370 (41.2)	35 (62.5)	0.003	362 (42.6)	64 (57.1)	0.005
Cognitive functions and mental health						
Cognitive function: MMSE[†]	29.0 (27,30)	28.0 (27,29)	0.050	29.0 (28,30)	28.0 (26,29)	<0.001
GDS score	2.2(2.7)	6.6(3.9)	<0.001	2.3(2.4)	6.4 (3.4)	<0.001
Nutritional and dietary status						
BMI (kg/m^2)	23.3 (2.7)	22.7 (3.0)	0.253	22.5 (3.2)	22.2 (3.4)	0.449
Food diversity	3.8 (2.0)	4.4 (2.1)	0.705	3.7 (2.0)	3.8 (2.2)	0.393
Meat or fish (≥once/2 days)	402 (44.8)	18 (32.1)	0.019	429 (50.5)	40 (35.7)	0.038
Vegetables or fruits (≥once/2 days)	839 (93.5)	50 (89.3)	0.339	828 (97.5)	108 (96.4)	0.711
Eating <3 meals per day	31 (3.5)	0 (0.0)	0.305	34 (4.0)	7 (6.3)	0.392
MNA-SF	12.5 (1.5)	12.6 (1.3)	0.161	12.4 (1.5)	12.6 (1.3)	0.301

Oral status						
Number of functional teeth	27.3 (2.8)	26.7 (2.8)	0.299	27.1 (2.0)	26.6 (2.7)	0.032

IADL, Instrumental Activities of Daily Living; MMSE, Mini-Mental State Examination; GDS, Geriatric Depression Scale; BMI, body mass index; MNA-SF, Mini Nutritional Assessment- Short Form; SD, standard deviation. *Chi squared test was used for categorical variables and nonpaired *t*-test and Mann-Whitney test were used for continuous variables. † Data is shown as median (interquartile range).

Table 3. Association between frailty and each variable by binary logistic regression

	Men						Women					
	Model 1			Model 2			Model 1			Model 2		
	OR	(95%CI)	*P* value	OR	(95%CI)	*P* value	OR	(95%CI)	*P* value	OR	(95%CI)	*P* value
Eating and living with others (ref.)	1.00			1.00			1.00			1.00		
Eating with others yet living alone	-	-	-	-	-	-	2.72	(1.1-7.0)	0.037	1.94	(0.72-5.28)	0.192
Eating alone yet living with others	3.49	(1.7-7.3)	0.001	2.49	(1.1-5.5)	0.026	2.93	(1.5-5.8)	0.002	2.16	(1.0-4.5)	0.038
Eating and living alone	1.93	(0.66-5.7)	0.229	1.29	(0.41-4.1)	0.664	2.01	(1.2-3.4)	0.008	1.52	(0.86-2.7)	0.150
Age				1.07	(1.0-1.1)	0.009				1.09	(1.0-1.1)	<0.001
Years of education				0.88	(0.81-0.96)	0.006				1.00	(0.91-1.1)	1.000
Chronic diseases												
≥2 chronic diseases				1.00	(0.40-2.5)	0.994				0.68	(0.35-1.3)	0.249
Cerebrovascular disease				2.41	(1.0-5.6)	0.039				2.85	(1.3-6.1)	0.008
Hypertension				0.99	(0.51-1.9)	0.967				1.18	(0.69-2.0)	0.555
Diabetes				1.66	(0.79-3.5)	0.183				1.07	(0.50-2.3)	0.868
Osteoporosis				2.24	(0.63-8.0)	0.214				1.79	(1.1-3.0)	0.029
Chronic kidney disease				2.07	(0.22-19.5)	0.524				2.51	(0.24-25.9)	0.440
Heart disease				2.00	(0.98-4.1)	0.056				1.89	(1.1-3.4)	0.031
Cancer				1.49	(0.74-3.0)	0.266				1.31	(0.68-2.5)	0.413
MMSE				1.03	(0.88-1.2)	0.719				0.83	(0.74-0.92)	0.001
Number of functional teeth				0.96	(0.89-1.0)	0.311				0.93	(0.86-1.0)	0.069

CI, confidence interval; MMSE, Mini-Mental State Examination; OR, odds ratio

Table 4. Association between each frailty domain and eating alone combined with living status by binary logistic regression*

Domains	Eating and living status	Men				Women			
		At risk n (%)	OR	(95%CI)	*P* value	At risk n (%)	OR	(95%CI)	*P* value
IADL	**Eating and living with others (ref.)**	25 (3.0)	1.00			9 (1.2)	1.00		
	Eating with others yet living alone	0 (0)	-	-	-	0 (0)	-	-	-
	Eating alone yet living with others	4 (6.3)	2.17	(0.71-6.6)	0.174	4 (7.8)	5.00	(1.4-17.4)	0.011
	Eating and living alone	0 (0)	-	-	-	2 (1.6)	0.89	(0.18-4.3)	0.880
Physical strength	**Eating and living with others (ref.)**	33 (4.0)	1.00			84 (11.1)	1.00		
	Eating with others yet living alone	0 (0)	-	-	-	6 (22.2)	1.52	(0.57-1.8)	0.404
	Eating alone yet living with others	2 (3.1)	0.42	(0.09-1.9)	0.256	10 (19.6)	1.42	(0.66-3.0)	0.370
	Eating and living alone	6 (14.0)	2.76	(1.0-7.6)	0.050	19 (15.1)	0.99	(0.56-1.8)	0.964
Nutrition/ Eating	**Eating and living with others (ref.)**	97 (11.6)	1.00			132 (17.4)	1.00		
	Eating with others yet living alone	0 (0)	-	-	-	5 (18.5)	0.93	(0.34-2.5)	0.881
	Eating alone yet living with others	13 (20.3)	1.63	(0.84-3.2)	0.148	10 (19.6)	1.03	(0.50-2.1)	0.941
	Eating and living alone	8 (18.6)	1.54	(0.69-3.5)	0.294	33 (26.2)	1.50	(0.96-2.3)	0.076
Socialization	**Eating and living with others (ref.)**	29 (3.5)	1.00			43 (4.5)	1.00		
	Eating with others yet living alone	0 (0)	-	-	-	3 (11.1)	2.56	(0.72-9.1)	0.149
	Eating alone yet living with others	5 (7.8)	2.31	(0.83-6.4)	0.108	7 (13.7)	3.33	(1.4-58.2)	0.008
	Eating and living alone	1 (2.3)	2.26	(0.86-5.0)	0.681	4 (3.2)	0.69	(0.24-2.0)	0.504
Memory	**Eating and living with others (ref.)**	262 (31.4)	1.00			282 (37.3)	1.00		
	Eating with others yet living alone	5 (41.7)	1.61	(0.50-5.2)	0.42	12 (44.4)	1.11	(0.55-2.6)	0.639
	Eating alone yet living with others	25 (39.1)	1.28	(0.75-2.2)	0.363	29 (56.9)	2.00	(1.1-3.6)	0.019
	Eating and living alone	8 (18.6)	0.46	(0.21-1.0)	0.051	49 (38.9)	1.01	(0.68-1.5)	0.964
Mood	**Eating and living with others (ref.)**	75 (9.0)	1.00			105 (13.9)	1.00		

Eating with others yet living alone	0 (0)	-	-	-	7 (25.9)	1.66	(0.67-4.1)	0.275
Eating alone yet living with others	15 (23.4)	2.47	(1.3-4.7)	0.006	16 (31.4	2.27	(1.2-4.3)	0.012
Eating and living alone	9 (20.9)	2.26	(1.0-5.0)	0.044	17 (13.5)	0.77	(0.44-1.4)	0.376

CI, confidence interval; OR, odds ratio. (-) could not calculate due to small number

*Adjusted variables: Age, years of education, number of chronic diseases

Table 5. Characteristics of study participants according to eating and living status in men

Variables	Eating and living with others (n= 834)	Eating with others yet living alone (n= 12)	Eating alone yet living with others (n=64)	Eating and living alone (n= 43)	*P* value
	Mean (SD) or n (%)				
Age	72.8 (5.4)	73.3 (5.2)	75.6 (6.3)	74.7 (6.5)	<0.001†
Education (years)	13.8 (2.8)	13.1 (4.4)	12.3 (3.5)	12.6 (3.0)	<0.001†
Family members					
Spouse	801 (96.2)	-	48 (75.0)	-	<0.001
Children	300 (36.0)	-	34 (53.10)	-	0.006
Number of family members	1.7 (1.2)	-	1.9 (1.1)	-	0.198
Social ties with family	8.0 (3.2)	8.0 (3.6)	7.4 (3.4)	7.8 (2.8)	0.531
Social ties with friends	8.0 (3.6)	8.8 (3.3)	7.6 (4.0)	8.1 (3.7)	0.744
Having ≥2 chronic diseases	355 (42.6)	3 (25.0)	27 (42.2)	20 (46.5)	0.617
Cognitive function: MMSE{	29.0 (27,30)	29.0 (27,30)	28.0 (26,29)	29.0 (28,29)	0.173
Having trouble with shopping	26 (3.1)	0 (0)	5 (7.8)	6 (14.0)	0.001‡
Preparing food by oneself	63 (7.6)	8 (66.7)	21 (33.3)	40 (93.0)	<0.001*
BMI (kg/m^2)	23.3 (2.7)	24.0 (3.6)	22.9 (3.2)	22.4 (3.3)	0.070
Food diversity	3.8 (2.0)	3.8 (3.1)	4.1 (2.0)	3.7 (2.0)	0.751
Meat or fish (≥once/2 days)	613 (73.5)	7 (58.3)	35 (54.7)	29 (67.4)	0.008†
Vegetables or fruits (≥once/2 days)	788 (94.5)	12 (100.0)	53 (82.8)	36 (83.7)	<0.001‡
Eating <3 meals/day	19 (2.3)	0 (0)	6 (9.4)	6 (14.0)	<0.001‡
MNA-SF	12.5 (1.5)	12.5 (1.5)	12.4 (1.6)	12.4 (1.6)	0.982
Food enjoyment	820 (98.3)	12 (100.0)	57 (89.1)	40 (93.0)	<0.001‡
Number of functional teeth	27.3 (2.7)	26.7 (3.6)	26.8 (4.1)	27.0 (1.8)	0.411
KCL score (1-20)	2.32 (2.1)	1.75 (1.4)	3.34 (2.8)	2.65 (2.1)	0.001†

BMI, body mass index; MNA-SF, Mini Nutritional Assessment- Short Form; SD, standard deviation; KCL, Kihon Checklist. Chi squared test was used for categorical variables and ANOVA test/ Kruskal-Wallis test were used for continuous variables. *Significant difference between "eating and living with others" group and other 3 groups ,† significant difference between "eating and living with others" group and "eating alone yet living with others" group, ‡significant difference between "eating and living with others" group and both "eating and living alone" and "eating alone yet living with others" group, §significant difference between "eating and living with others" group and "eating and living alone" group. {Data is shown as median (interquartile range).

Table 6. Characteristics of study participants according to eating and living status in women

Variables	Eating and living with others (n=757)	Eating with others yet living alone (n= 27)	Eating alone yet living with others (n=51)	Eating and living alone (n=126)	*P* value
	Mean (SD) or n (%)				
Age	72.2 (5.3)	75.4 (5.5)	74.8 (5.1)	74.6 (5.9)	<0.001*
Education (years)	11.9 (2.2)	11.1 (1.8)	11.0 (2.3)	11.6 (2.6)	0.008†
Family members					
Spouse	625 (82.6)	-	16 (31.4)	-	<0.001
Children	341 (45.0)	-	42 (82.4)	-	<0.001
Number of family members	1.7 (1.2)	-	2.2 (1.3)	-	0.005
Social ties with family	8.9 (3.2)	8.9 (3.0)	8.0 (3.0)	8.3 (3.4)	0.616
Social ties with friends	8.1 (3.6)	10.0 (3.4)	8.1 (3.5)	8.3 (3.7)	0.071
Having ≥2 chronic diseases	321 (42.4)	15 (55.6)	28 (54.9)	62 (49.2)	0.110
Cognitive function: MMSE{	29.0 (27,30)	28.0 (26,29)	28 (26,29)	29 (27,30)	0.097
Having trouble with shopping	38 (5.0)	3 (11.1)	9 (17.6)	7 (5.6)	0.002†
Preparing food by oneself	696 (92.4)	24 (88.9)	48 (94.1)	126 (100.0)	<0.001§
BMI (kg/m^2)	22.4 (3.1)	24.1 (3.7)	22.6 (3.6)	22.1 (3.4)	0.038‖
Food diversity	3.8 (2.0)	3.7 (2.3)	3.8 (2.4)	3.3 (2.0)	0.123
Meat or fish (≥once/2 days)	585 (77.3)	18 (66.7)	31 (61.8)	90 (71.4)	0.024†
Vegetables or fruits (≥once/2 days)	739 (97.6)	27 (100.0)	48 (94.1)	122 (96.8)	0.362
Eating <3 meals/day	26 (3.4)	1 (3.7)	2 (3.9)	12 (9.5)	0.020§
MNA-SF	12.4 (1.5)	12.3 (1.5)	12.4 (1.4)	12.6 (1.3)	0.765
Food enjoyment	742 (98.0)	27 (100.0)	44 (86.3)	120 (96.0)	<0.001†
Number of functional teeth	27.0 (2.1)	27.3 (2.0)	27.2 (1.9)	26.9 (2.5)	0.827
KCL score (1-20)	2.82 (2.4)	3.78 (2.2)	4.18 (3.2)	3.60 (2.7)	<0.001‡

BMI, body mass index; MNA-SF, Mini Nutritional Assessment- Short Form; SD, standard deviation; KCL, Kihon Checklist. Chi squared test was used for categorical variables and ANOVA test/ Kruskal-Wallis test were used for continuous variables. *Significant difference between "eating and living with others" group and other 3 groups ,† significant difference between "eating and living with others" group and "eating alone yet living with others" group, ‡significant difference between "eating and living with others" group and both "eating and living alone" and "eating alone yet living with others" group, §significant difference between "eating and living with others" group and "eating and living alone" group , ||significant difference between "eating and living with others" group and "eating with others yet living alone" group. {Data is shown as median (interquartile range).

Table 7. Food group factor loading from principal component analysis

Food groups	Dietary pattern		
	1 Fish-Tofu-Vegetables-Fruits (Japanese side dishes)	2 Rice-fish- miso soup (Japanese main dishes)	3 Noodles
Low fat milk	0.07	0.16	0.07
Full-fat milk	0.13	**-0.31**	-0.02
Poultry	0.18	0.13	0.15
Pork and beef	0.25	-0.09	0.05
Ham sausages and bacon	0.08	-0.29	0.23
Liver	0.00	0.21	0.25
Squid Octopus Shrimp Clam	0.13	0.17	**0.35**
Small fish with bones	0.29	0.28	0.02
Canned tuna	0.11	0.05	0.27
Dried fish and salted fish	0.18	**0.38**	0.11
Oily fish	0.29	**0.38**	0.17
Non-oily fish	**0.31**	0.26	0.21
Eggs	0.16	0.05	0.18
Tofu and tofu products	**0.39**	0.15	0.00
Natto*	0.24	0.28	-0.04
Potatoes	**0.44**	0.21	-0.06
Salted green and yellow vegetable pickles	**0.31**	0.14	-0.10
Other salted vegetable pickles	0.21	0.01	-0.19
Raw vegetables used in salad (Cabbage and lettuce)	**0.48**	-0.22	0.06
Green leafy vegetables	**0.64**	-0.02	-0.01
Cabbage and Chinese cabbage	**0.61**	-0.01	0.01
Carrots and pumpkins	**0.67**	0.04	-0.11
Radishes and turnips	**0.56**	0.11	-0.02
Other root vegetables	**0.68**	-0.02	-0.07
Tomatoes	**0.39**	-0.15	0.10
Mushrooms	**0.58**	0.11	0.10
Seaweeds	**0.55**	0.15	0.02
Western sweets	-0.07	**-0.46**	-0.10
Japanese sweets	0.04	**-0.33**	-0.05
Rice crackers	-0.05	**-0.35**	-0.11
Ice cream	-0.09	-0.20	0.15

Citrus fruit	0.28	-0.05	0.09
Persimmons and kiwi	**0.32**	0.01	0.12
Other fruits	**0.39**	-0.19	-0.15
Mayonnaise and salad dressing	0.15	**-0.45**	0.09
Bread	-0.09	**-0.51**	0.12
Buckwheat noodles	-0.15	0.13	**0.56**
Japanese wheat noodles	-0.13	0.05	**0.44**
Instant noodles and Chinese noodles	-0.30	0.10	**0.45**
Spaghetti and macaroni	-0.09	-0.01	**0.40**
Green tea	0.22	0.06	-0.15
Black and oolong tea	0.04	-0.10	0.22
Coffee	0.02	-0.22	0.11
Cola and sweetened soft drinks	-0.24	-0.10	0.10
Fruit juice	-0.01	-0.01	0.12
Rice	**-0.38**	**0.34**	**-0.64**
Miso soup	-0.18	**0.35**	**-0.43**

*Natto: Fermented soybeans
Factor loadings with absolute value >0.3 are shown in bold.

Table 8. Dietary pattern scores in both genders

Dietary pattern score	Men	Women	*P* value*
Dietary patterns derived from Principal component analysis			
Dietary pattern 1: Japanese side dishes	180.9(175.4)	241.0(149.8)	<0.001
Dietary pattern 2: Japanese main dishes	59.4(122.5)	55.2(89.4)	0.090
Dietary pattern 3: Noodles	-149.8(165.7)	-160.8(120.0)	0.469
Japanese diet score	3.0 (3.0)	5.0(3.0)	<0.001

Scores are shown as median (interquartile range)
**P* value from Mann Whitney test.

Table 9. Characteristics of participants based on sarcopenia status

Variables	Sarcopenia n=60	Non-sarcopenia n=1181	*P* value
Sociodemographic variables			
Age (years)	79.1 (5.7)	74.4 (5.3)	<0.001
Economic status %			
Affluent	31.7	29.1	0.771
Living alone %	15.0	12.5	0.575
Medical histories			
Multimorbidity %	33.3	37.0	0.368
Number of medication	2.0 (5.0)	2.0 (3.0)	0.295
Cognitive function and mental health			
MMSE score[a]	28.0 (3.0)	29.0 (2.0)	<0.001
GDS score[a]	2.0 (4.0)	1.0 (4.0)	0.014
Physical activity and nutritional status			
Physical activity (Mets/day)	102.9 (257.1)	240.0 (445.7)	0.001
BMI (kg/m^2)	19.9 (2.6)	22.4 (2.9)	<0.001
Energy intake (kcal/day)	2071.9 (677.7)	2099.3 (593.8)	0.729
Dietary pattern score			
DP1[a]	202.9 (205.2)	210.3 (170.1)	0.409
DP2[a]	43.7 (96.7)	57.6 (107.1)	0.298
DP3[a]	-150.6 (98.5)	-157.1 (140.5)	0.849
Japanese diet score[a]	4.0 (2.0)	4.0 (2.0)	0.816

Note: a: Showing Median (Interquartile range), others are Mean (Standard Deviation), MMSE: Mini-mental state examination, GDS: Geriatric depression scale, BMI: Body mass index, DP: Dietary pattern, Chi squared test was used for categorical variables and nonpaired *t*-test and Mann-Whitney test were used for continuous variable

Table 10. Characteristics of participants based on sarcopenia status among gender

Variables	Men			Women		
	Sarcopenia n=25	Non-sarcopenia n=621	*P* value	Sarcopenia n=35	Non-sarcopenia n=560	*P* value
Sociodemographic variables						
Age (years)	79.0 (5.1)	74.6 (5.5)	<0.001	79.1 (6.2)	74.1 (5.2)	<0.001
Economic status %						
Affluent	20.0	26.5	0.714	32.0	40.0	0.559
Living alone %	8.0	8.1	0.993	20.0	17.5	0.707
Medical histories						
Multimorbidity %	44.0	38.0	0.800	25.7	35.9	0.075
Number of medication	3.0 (6.0)	2.0 (4.0)	0.256	2.0 (5.0)	2.0 (3.0)	0.639
Cognitive function and mental health						
MMSE score[a]	29.0 (3.0)	29.0 (2.0)	0.072	28.0 (3.0)	29.0 (2.0)	0.001
GDS score[a]	3.0 (6.5)	1.0 (3.0)	0.006	2.0 (3.5)	2.0 (4.0)	0.536

Physical activity and nutritional status						
Physical activity (Mets/day)	102.9 (197.1)	257.1 (462.9)	0.006	111.4 (325.7)	205.7 (454.3)	0.044
BMI (kg/m^2)	20.2 (2.0)	22.8 (2.7)	<0.001	19.8 (3.0)	22.0 (3.1)	<0.001
Energy intake (kcal/day)	2298.2 (687.9)	2243.3 (602.1)	0.657	1910.3 (631.2)	1939.7 (542.0)	0.758
Dietary pattern score						
DP1[a]	96.8 (186.4)	186.6 (138.4)	0.045	244.8 (159.6)	241.0 (151.6)	0.887
DP2[a]	84.2 (155.3)	59.0 (121.5)	0.616	31.6 (74.1)	57.6(92.1)	0.048
DP3[a]	-166.3 (153.4)	-149.7 (165.9)	0.485	-146.9(95.5)	-161.1 (121.2)	0.301
Japanese diet score[a]	4.0 (2.0)	3.0 (3.0)	0.572	4.0 (2.3)	5.0 (3.0)	0.698

Note: a: Showing Median (Interquartile range), others are Mean (Standard Deviation), MMSE: Mini-mental state examination, GDS: Geriatric depression scale, BMI: Body mass index, DP: Dietary pattern, Chi squared test was used for categorical variables and nonpaired *t*-test and Mann-Whitney test were used for continuous variable

Table 11. Association between dietary patterns and sarcopenia stratified by gender

	Men						Women					
	Model 1			Model 2			Model 1			Model 2		
	OR	(95%CI)	*P* value	OR	(95%CI)	*P* value	OR	(95%CI)	*P* value	OR	(95%CI)	*P* value
DP1												
T1	3.34	(1.16-9.61)	0.025	3.67	(1.20-11.2)	0.032	1.31	(0.57-3.01)	0.523	1.17	(0.47-2.91)	0.821
T2	1.52	(0.45-5.16)	0.500	1.46	(0.41-5.28)	0.514	0.77	(0.31-1.89)	0.564	0.60	(0.22-1.65)	0.300
T3 (reference)	1			1			1			1		
DP2												
T1	1.10	(0.39-3.12)	0.862	1.15	(0.39-3.40)	0.805	2.22	(0.87-5.66)	0.094	2.71	(0.99-7.46)	0.041
T2	1.47	(0.54-3.99)	0.450	1.59	(0.56-4.53)	0.404	1.78	(0.67-4.70)	0.246	1.62	(0.58-4.52)	0.336
T3 (reference)	1			1			1			1		
DP3												
T1	0.77	(0.25-2.36)	0.643	0.69	(0.22-2.17)	0.604	0.59	(0.22-1.58)	0.295	0.51	(0.18-1.41)	0.287
T2	1.48	(0.56-3.89)	0.431	1.30	(0.45-3.75)	0.442	1.37	(0.61-3.06)	0.444	1.07	(0.45-2.54)	0.664
T3 (reference)	1			1			1			1		
Japanese diet score												
Low	3.42	(1.01-11.5)	0.047	5.10	(1.27-20.3)	0.021	2.03	(0.85-4.86)	0.110	2.90	(0.95-8.88)	0.062
Medium	2.63	(0.80-8.64)	0.110	3.80	(1.03-14.0)	0.044	0.84	(0.26-2.73)	0.771	0.97	(0.27-3.45)	0.956
High (reference)	1			1			1			1		

Note:
OR: Odd ratio, CI: Confidence interval, DP: Dietary pattern
Model 1 adjusted for age
Model 2 further adjusted for economic circumstance, living alone, body mass index, energy intake, multimorbidity, physical activity

8. Appendices

Appendix 1. Kihon checklist questionnaire

(1)	バスや電車で１人で外出していますか	1　はい	2　いいえ
(2)	日用品の買い物をしていますか	1　はい	2　いいえ
(3)	友人の家を訪ねていますか	1　はい	2　いいえ
(4)	家族や友人の相談にのっていますか	1　はい	2　いいえ
(5)	階段を手すりや壁をつたわらずに昇っていますか	1　はい	2　いいえ
(６)	椅子に座った状態から何もつかまらずに立ち上がっていますか	1　はい	2　いいえ
(７)	15 分間位続けて歩いていますか	1　はい	2　いいえ
(８)	この１年間に転んだことがありますか	1　はい	2　いいえ
(９)	転倒に対する不安は大きいですか	1　はい	2　いいえ
(10)	６ヶ月間で２～３kg 以上の体重減少はありましたか	1　はい	2　いいえ
(11)	半年前に比べて堅いものが食べにくくなりましたか	1　はい	2　いいえ
(12)	お茶や汁物等でむせることがありますか	1　はい	2　いいえ
(13)	口の渇きが気になりますか	1　はい	2　いいえ
(14)	週に１回以上は外出していますか	1　はい	2　いいえ
(15)	昨年と比べて外出の回数が減っていますか	1　はい	2　いいえ
(16)	周りの人から「いつも同じ事を聞く」などの物忘れがあると 言われますか	1　はい	2　いいえ
(17)	自分で電話番号を調べて、電話をかけることをしていますか	1　はい	2　いいえ
(18)	今日が何月何日かわからない時がありますか	1　はい	2　いいえ
(19)	ここ２週間で毎日の生活に充実感がない	1　はい	2　いいえ
(20)	ここ２週間でこれまで楽しんでやれていたことが 楽しめなくなった	1　はい	2　いいえ

(21)	ここ２週間で以前は楽にできていたことが、 今ではおっくうに感じられる	1　はい	2　いいえ
(22)	ここ２週間で自分が役に立つ人間だと思えない	1　はい	2　いいえ
(23)	ここ２週間でわけもなく疲れたような感じがする	1　はい	2　いいえ
(24)	過去１年間に転んだことがありますか？	1　はい	2　いいえ
(25)	身長　　体重　　BMI ＝		

Appendix 2. Frailty domains assessed by Kihon Checklist (KCL)

Domain name	Questions from KCL	Cut-off score for at risk
Instrumental activities of daily living (IADL)	1-5	≥3
Physical strength	6-10	≥3
Nutrition	11,12	2
Eating	13-15	≥2
Socialization	16	1
Memory	18-20	≥1
Mood	21-25	≥2

Appendix 3. Brief self-administered diet history questionnaire (BDHQ)

ID (担当者記入欄)

a □□□□□□□□□

b □□□□□□□□□　　c □□□□□□□□□

0 0 1

あなたの食習慣についておたずねします
最近1か月間の食習慣について、お答え下さい

- たくさん質問がありますが、あまり考え込まずに、第一印象でお答えください。
- 質問の内容が難しい場合には、あなたの家庭で食事の準備をおもにしているひとといっしょに考えながら、答えてください。

お答えいただいた内容は、食べ物と健康との関連を明らかにし、だれもが健康な生活を送れるようにするための貴重な資料として活用させていただきます。
その場合、結果はたくさんのひとたちの平均値などの数値として公表されます。
あなた個人がわかるような形で公表されることは絶対にありません。

【書き方】
- 太い黒の鉛筆、或いはボールペンで記入してください。
- この用紙は機械で読み取ります。
文字は枠線にかからないように丁寧にご記入ください。

Vの記入例
- 枠線の中にある3点を結んで下さい。
- まわりの枠線に線が触れないようにチェック V をご記入ください。

良い例 V

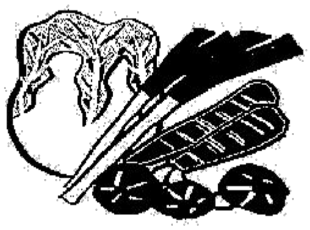
悪い例

数字の記入例
0 1 2 3 4
5 6 7 8 9

濃く、ていねいに

今日（この質問票に答える日）の日付

平成 □□ 年 □□ 月 □□ 日



では、スタート！

あなたは、この1か月のあいだ、
以下の食べ物をどのくらいの頻度で食べていましたか？
もっともあてはまる回答をひとつ選んで、チェックしてください。

0	0	2

コップ1杯くらいの牛乳・ヨーグルト1人前		鶏肉（挽き肉を含む）	豚肉・牛肉（挽き肉を含む）
低脂肪	普通・高脂肪		
□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上
□ 毎日1回	□ 毎日1回	□ 毎日1回	□ 毎日1回
□ 週4〜6回	□ 週4〜6回	□ 週4〜6回	□ 週4〜6回
□ 週2〜3回	□ 週2〜3回	□ 週2〜3回	□ 週2〜3回
□ 週1回	□ 週1回	□ 週1回	□ 週1回
□ 週1回未満	□ 週1回未満	□ 週1回未満	□ 週1回未満
□ 飲まなかった/食べなかった	□ 飲まなかった/食べなかった	□ 食べなかった	□ 食べなかった

ハム・ソーセージ・ベーコン	レバー	いか・たこ・えび・貝	骨ごと食べる魚
□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上
□ 毎日1回	□ 毎日1回	□ 毎日1回	□ 毎日1回
□ 週4〜6回	□ 週4〜6回	□ 週4〜6回	□ 週4〜6回
□ 週2〜3回	□ 週2〜3回	□ 週2〜3回	□ 週2〜3回
□ 週1回	□ 週1回	□ 週1回	□ 週1回
□ 週1回未満	□ 週1回未満	□ 週1回未満	□ 週1回未満
□ 食べなかった	□ 食べなかった	□ 食べなかった	□ 食べなかった

ツナ缶（まぐろの油漬け）	魚の干物・塩蔵魚（塩さば・塩鮭・あじの干物など）	脂が乗った魚（いわし・さば・さんま・ぶり・にしん・うなぎ・まぐろトロなど）	脂が少なめの魚（さけ・ます・白身の魚・淡水魚・かつおなど）
□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上
□ 毎日1回	□ 毎日1回	□ 毎日1回	□ 毎日1回
□ 週4〜6回	□ 週4〜6回	□ 週4〜6回	□ 週4〜6回
□ 週2〜3回	□ 週2〜3回	□ 週2〜3回	□ 週2〜3回
□ 週1回	□ 週1回	□ 週1回	□ 週1回
□ 週1回未満	□ 週1回未満	□ 週1回未満	□ 週1回未満
□ 食べなかった	□ 食べなかった	□ 食べなかった	□ 食べなかった

0	0	3

たまご（鶏の卵1個程度）	とうふ・厚揚げ	納豆	いも（すべての種類）
□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上
□ 毎日1回	□ 毎日1回	□ 毎日1回	□ 毎日1回
□ 週4～6回	□ 週4～6回	□ 週4～6回	□ 週4～6回
□ 週2～3回	□ 週2～3回	□ 週2～3回	□ 週2～3回
□ 週1回	□ 週1回	□ 週1回	□ 週1回
□ 週1回未満	□ 週1回未満	□ 週1回未満	□ 週1回未満
□ 食べなかった	□ 食べなかった	□ 食べなかった	□ 食べなかった

漬物		生野菜（サラダ）	料理に使った野菜
緑の濃い葉野菜	その他すべて（梅干は除く）	レタス・キャベツ千切りなど（トマトは除く）	緑の濃い葉野菜（ブロッコリーを含む）
□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上
□ 毎日1回	□ 毎日1回	□ 毎日1回	□ 毎日1回
□ 週4～6回	□ 週4～6回	□ 週4～6回	□ 週4～6回
□ 週2～3回	□ 週2～3回	□ 週2～3回	□ 週2～3回
□ 週1回	□ 週1回	□ 週1回	□ 週1回
□ 週1回未満	□ 週1回未満	□ 週1回未満	□ 週1回未満
□ 食べなかった	□ 食べなかった	□ 食べなかった	□ 食べなかった

料理に使った野菜（漬物・サラダ以外）			
キャベツ・白菜	にんじん・かぼちゃ	だいこん・かぶ	その他の根菜すべて（たまねぎ・ごぼう・れんこんなど）
□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上
□ 毎日1回	□ 毎日1回	□ 毎日1回	□ 毎日1回
□ 週4～6回	□ 週4～6回	□ 週4～6回	□ 週4～6回
□ 週2～3回	□ 週2～3回	□ 週2～3回	□ 週2～3回
□ 週1回	□ 週1回	□ 週1回	□ 週1回
□ 週1回未満	□ 週1回未満	□ 週1回未満	□ 週1回未満
□ 食べなかった	□ 食べなかった	□ 食べなかった	□ 食べなかった

0	0	4

トマト・トマトケチャップ・トマト煮込み・トマトシチュー	きのこ(すべての種類)	海草(すべての種類)(だし用は除く)	お菓子・おやつ 洋菓子・クッキー・ビスケット
□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上
□ 毎日1回	□ 毎日1回	□ 毎日1回	□ 毎日1回
□ 週4~6回	□ 週4~6回	□ 週4~6回	□ 週4~6回
□ 週2~3回	□ 週2~3回	□ 週2~3回	□ 週2~3回
□ 週1回	□ 週1回	□ 週1回	□ 週1回
□ 週1回未満	□ 週1回未満	□ 週1回未満	□ 週1回未満
□ 食べなかった	□ 食べなかった	□ 食べなかった	□ 食べなかった

お菓子・おやつ			果物
和菓子	せんべい・もち・お好み焼きなど	アイスクリーム	みかんなどの柑橘(かんきつ)類
□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上
□ 毎日1回	□ 毎日1回	□ 毎日1回	□ 毎日1回
□ 週4~6回	□ 週4~6回	□ 週4~6回	□ 週4~6回
□ 週2~3回	□ 週2~3回	□ 週2~3回	□ 週2~3回
□ 週1回	□ 週1回	□ 週1回	□ 週1回
□ 週1回未満	□ 週1回未満	□ 週1回未満	□ 週1回未満
□ 食べなかった	□ 食べなかった	□ 食べなかった	□ 食べなかった

果物		マヨネーズ・ドレッシング	パン(おかずパン・菓子パンも含む)
かき・いちご・キウイ	その他のすべての果物		
□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上
□ 毎日1回	□ 毎日1回	□ 毎日1回	□ 毎日1回
□ 週4~6回	□ 週4~6回	□ 週4~6回	□ 週4~6回
□ 週2~3回	□ 週2~3回	□ 週2~3回	□ 週2~3回
□ 週1回	□ 週1回	□ 週1回	□ 週1回
□ 週1回未満	□ 週1回未満	□ 週1回未満	□ 週1回未満
□ 食べなかった	□ 食べなかった	□ 食べなかった	□ 食べなかった

0	0	5

麺類		
そば	うどん・ひやむぎ・そうめん	らーめん・インスタントらーめん
□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上
□ 毎日1回	□ 毎日1回	□ 毎日1回
□ 週4～6回	□ 週4～6回	□ 週4～6回
□ 週2～3回	□ 週2～3回	□ 週2～3回
□ 週1回	□ 週1回	□ 週1回
□ 週1回未満	□ 週1回未満	□ 週1回未満
□ 食べなかった	□ 食べなかった	□ 食べなかった

麺類	飲み物		
スパゲッティ・マカロニなど	緑茶	紅茶・ウーロン茶（中国茶）	コーヒー
	□ 毎日4杯以上	□ 毎日4杯以上	□ 毎日4杯以上
□ 毎日2回以上	□ 毎日2～3杯	□ 毎日2～3杯	□ 毎日2～3杯
□ 毎日1回	□ 毎日1杯	□ 毎日1杯	□ 毎日1杯
□ 週4～6回	□ 週4～6杯	□ 週4～6杯	□ 週4～6杯
□ 週2～3回	□ 週2～3杯	□ 週2～3杯	□ 週2～3杯
□ 週1回	□ 週1杯	□ 週1杯	□ 週1杯
□ 週1回未満	□ 週1杯未満	□ 週1杯未満	□ 週1杯未満
□ 食べなかった	□ 飲まなかった	□ 飲まなかった	□ 飲まなかった

飲み物	
コーラ・ジュース（ｽﾎﾟｰﾂﾄﾞﾘﾝｸも含む）	100%果物ジュース 100%野菜ジュース
□ 毎日4杯以上	□ 毎日4杯以上
□ 毎日2～3杯	□ 毎日2～3杯
□ 毎日1杯	□ 毎日1杯
□ 週4～6杯	□ 週4～6杯
□ 週2～3杯	□ 週2～3杯
□ 週1杯	□ 週1杯
□ 週1杯未満	□ 週1杯未満
□ 飲まなかった	□ 飲まなかった

↓

コーヒー・紅茶には砂糖を入れますか
□ いつも
□ ときどき
□ いいえ

006			

朝食（主食を含むもの）を食べた頻度	「平均的な1日」に食べたごはんとみそ汁 ごはん	みそ汁	玄米・胚芽米を食べたり、ごはんに麦や雑穀を混ぜて食べることはありますか
□ 毎朝	□ 8杯以上	□ 8杯以上	□ いつも
□ 週に6回	□ 6~7杯	□ 6~7杯	□ ときどき
□ 週に5回	□ 5杯	□ 5杯	□ まれに
□ 週に4回	□ 4杯	□ 4杯	□ いいえ
□ 週に3回	□ 3杯	□ 3杯	
□ 週に2回	□ 2杯	□ 2杯	
□ 週に1回	□ 1杯	□ 1杯	
□ 週に1回未満	□ 1杯未満	□ 1杯未満	
□ 食べなかった	□ 食べなかった	□ 食べなかった	

お酒（薬用酒は含めません）

頻度	1回に飲んだ典型的なお酒の種類の組み合わせとその量 日本酒	ビール(大瓶で)	焼酎・酎ハイ・泡盛（焼酎・泡盛水割りで）
□ 毎日			
□ 週に6回			
□ 週に5回	□ 4合以上	□ 4本以上	□ 4杯以上
□ 週に4回	□ 3合	□ 3本	□ 3杯
□ 週に3回	□ 2合	□ 2本	□ 2杯
□ 週に2回	□ 1合	□ 1本	□ 1杯
□ 週に1回	□ 0.5合	□ 0.5本	□ 0.5杯
□ 週に1回未満	□ 0.5合未満	□ 0.5本未満	□ 0.5杯未満
□ 飲まなかった	□ 飲まなかった	□ 飲まなかった	□ 飲まなかった

「飲まなかった」の場合は、次のページに進んでください。

お酒（薬用酒は含めません）

1回に飲んだ典型的なお酒の種類の組み合わせとその量 ウイスキー類（ダブルで）	ワイン（ワイングラスで）
□ 4杯以上	□ 4杯以上
□ 3杯	□ 3杯
□ 2杯	□ 2杯
□ 1杯	□ 1杯
□ 0.5杯	□ 0.5杯
□ 0.5杯未満	□ 0.5杯未満
□ 飲まなかった	□ 飲まなかった

主食を含む朝食とは
- ごはん
- パン
- コーンフレーク
- めん類

などのある朝食のことをいいます。

飲み物だけ、サラダだけ、おかずだけのような場合は含みません。

あなたは、この1か月のあいだ、
以下の食べ物をどのくらいの頻度で食べていましたか？
もっともあてはまる回答をひとつ選んで、チェックしてください。

0	0	7

魚を使った料理（いか・たこ・えび・貝も含む）			
さしみ・すし（定食一人前程度の量）	焼き魚	煮物・鍋物・汁物・みそ汁	てんぷら・揚げ魚（定食一人前程度の量）
□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上
□ 毎日1回	□ 毎日1回	□ 毎日1回	□ 毎日1回
□ 週4～6回	□ 週4～6回	□ 週4～6回	□ 週4～6回
□ 週2～3回	□ 週2～3回	□ 週2～3回	□ 週2～3回
□ 週1回	□ 週1回	□ 週1回	□ 週1回
□ 週1回未満	□ 週1回未満	□ 週1回未満	□ 週1回未満
□ 食べなかった	□ 食べなかった	□ 食べなかった	□ 食べなかった

肉を使った料理（ハム・ソーセージなどの肉加工品も含む）			
焼肉・ステーキ・グリル	ハンバーグ・カレー・ミートソースなどの洋風の料理	揚げ物・てんぷら（定食一人前程度の量）	炒め物
□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上
□ 毎日1回	□ 毎日1回	□ 毎日1回	□ 毎日1回
□ 週4～6回	□ 週4～6回	□ 週4～6回	□ 週4～6回
□ 週2～3回	□ 週2～3回	□ 週2～3回	□ 週2～3回
□ 週1回	□ 週1回	□ 週1回	□ 週1回
□ 週1回未満	□ 週1回未満	□ 週1回未満	□ 週1回未満
□ 食べなかった	□ 食べなかった	□ 食べなかった	□ 食べなかった

肉を使った料理
和風の煮物・鍋物・どんぶり物・汁物・みそ汁
□ 毎日2回以上
□ 毎日1回
□ 週4～6回
□ 週2～3回
□ 週1回
□ 週1回未満
□ 食べなかった

もっともあてはまる回答をひとつ選んで、チェックしてください。

麺類のスープ・汁を飲む量は	家庭での味付けは外食と比べて	お肉（牛肉や豚肉）の脂身は
□ ほとんど全部	□ 薄口	□ 好んで食べていた
□ 8割位	□ 少し薄口	□ やや好んで食べていた
□ 4～6割	□ 同じくらい	□ 好きでも嫌いでもない
□ 2割位	□ 少し濃い口	□ あまり食べなかった
□ ほとんど飲まない	□ 濃い口	□ ほとんど食べなかった

0	0	8

食事のときに使うしょうゆ・ソース	
頻度は	量は
□ 必ず使う	□ かなり多め
□ よく使う	□ やや多め
□ ときどき使う	□ ふつう
□ ほとんど使わない	□ やや少なめ
□ まったく使わない	□ かなり少なめ

外食の定食1人前と、自分が普段食べている量を比べると		食べる速さは
おかずの量は	ごはんの量は	
□ 家のほうがかなり多い	□ 家のほうがかなり多い	□ かなり速い
□ 家のほうが少し多い	□ 家のほうが少し多い	□ やや速い
□ ほぼ同じくらい	□ ほぼ同じくらい	□ ふつう
□ 外食のほうが少し多い	□ 外食のほうが少し多い	□ やや遅い
□ 外食のほうがかなり多い	□ 外食のほうがかなり多い	□ かなり遅い

季節によって食べ方が大きくちがう食べ物			この1か月間に健康補助食品を使いましたか
この1年間でもっともよく食べた季節を思い出して、その頃の食べ方についてお答えください。			
みかんなどの柑橘（かんきつ）類	かき（柿）	いちご	
□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上	□ 毎日2回以上
□ 毎日1回	□ 毎日1回	□ 毎日1回	□ 毎日1回
□ 週4～6回	□ 週4～6回	□ 週4～6回	□ 週4～6回
□ 週2～3回	□ 週2～3回	□ 週2～3回	□ 週2～3回
□ 週1回	□ 週1回	□ 週1回	□ 週1回
□ 週1回未満	□ 週1回未満	□ 週1回未満	□ 週1回未満
□ 食べなかった	□ 食べなかった	□ 食べなかった	□ 使わなかった

0	0	9

もっともあてはまる回答をひとつ選んで、チェックしてください。

最近、食事習慣を意識的に変えましたか	現在、医師・栄養士・その他専門家の指導のもとで、食事のコントロールをしていますか	この質問票におもに答えるひとは
はい → ☐ 3年以上前 → ☐ 1～2年前 → ☐ 1年前以内 ☐ いいえ	☐ はい ☐ いいえ	☐ 本人 ☐ 配偶者 ☐ 娘 ☐ その他

あなたに適した食事量を計算するために必要です。必ずご記入ください。

性別 男性 ☐　女性 ☐	生年月日 明治・大正 ☐　昭和 ☐　平成 ☐　□□年 □□月 □□日	
身長 □□□.□ cm	体重 □□□.□ kg	
<女性の方のみ> 妊娠中・授乳中の方は下記該当に記載（もしくはチェック）下さい。 妊娠 □□ 週目　☐ 授乳中		

質問はこれで終わりです。ご協力ありがとうございました。

0	1	0

メモ

Appendix 4. Mean daily intake of total energy and selected nutrients by dietary pattern score

Gender	DP1		Total Energy (kcal)	Protein (g)	Animal Protein (g)	Plant Protein (g)	Carbohydrate (g)	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)	Vitamin D (µg)	Vitamin C (mg)	Total Fiber (g)	n-3 fatty acid (g)	PUFA/SAFA ratio
Men	T1	Mean	2254.24	77.10	44.38	32.72	278.42	4935	2536.71	609.68	273.14	17.24	98.88	11.90	2.90	0.95
		SD	612.71	17.41	18.10	5.73	49.76	1045	528.44	204.00	49.40	12.16	38.94	2.61	0.98	0.29
	T2	Mean	2175.18	85.11	51.09	34.02	257.51	5242	3229.54	736.06	320.47	20.15	144.80	15.25	3.45	0.94
		SD	592.02	14.61	15.93	5.89	42.76	935	467.36	162.50	46.47	10.74	37.42	2.85	0.83	0.21
	T3	Mean	2306.11	96.46	60.47	35.99	247.70	5726	4076.65	902.91	377.49	24.94	200.76	19.56	4.01	0.95
		SD	606.05	17.86	19.27	5.99	39.69	1039	628.79	210.93	59.98	13.03	49.79	3.32	1.03	0.21
		P value	0.051	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.679
Women	T1	Mean	1907.37	86.85	53.66	33.19	280.30	5133	3071.74	747.90	307.28	22.49	138.07	13.98	3.44	0.85
		SD	542.91	14.17	15.89	4.26	35.24	881	424.41	178.06	42.59	11.66	37.61	2.11	0.88	0.18
	T2	Mean	1842.72	96.64	61.88	34.76	264.03	5503	3731.78	872.70	357.85	26.95	179.79	17.15	3.90	0.86
		SD	505.91	14.29	15.44	4.28	31.55	853	393.95	177.14	41.33	11.39	41.12	1.98	0.87	0.16
	T3	Mean	2063.92	104.11	66.82	37.29	258.13	5691	4530.92	983.57	409.05	29.34	234.92	21.82	4.20	0.91
		SD	569.42	15.99	17.46	5.24	31.80	904	672.90	212.94	56.69	13.04	56.94	4.01	0.98	0.18
		P value	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.02

DP: Dietary pattern, SD: Standard deviation
T: tertile as T1 is the lowest tertile and T3 is the highest tertile
ANOVA for normally, and Kruskal-Wallis test for non-normally distributed data

Gender	DP2		Total Energy (kcal)	Protein (g)	Animal Protein (g)	Plant Protein (g)	Carbohydrate (g)	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)	Vitamin D (µg)	Vitamin C (mg)	Total Fiber (g)	n-3 fatty acid (g)	PUFA/SAFA ratio
Men	T1	Mean	2324.40	87.50	53.39	34.11	250.64	5265	3416.06	803.46	324.28	19.36	156.60	16.00	3.47	0.83
		SD	583.68	19.12	19.71	6.12	40.05	1090	798.57	220.95	66.97	11.84	58.14	4.33	0.98	0.18
	T2	Mean	2152.30	88.54	54.87	33.68	250.51	5379	3438.08	774.12	334.76	22.23	159.83	16.07	3.63	0.95
		SD	617.21	16.57	16.76	6.06	41.04	1037	770.25	204.86	61.99	11.57	58.49	4.07	1.03	0.21
	T3	Mean	2258.62	82.66	47.72	34.94	282.41	5261	2990.69	671.43	312.18	20.77	128.15	14.66	3.26	1.06
		SD	604.55	19.15	19.66	5.83	49.06	1045	856.24	235.98	71.52	13.62	56.87	4.37	1.12	0.27
		P value	0.008	0.001	<0.001	0.043	<0.001	0.321	<0.001	<0.001	0.001	0.025	<0.001	0.001	0.003	<0.001
Women	T1	Mean	2018.70	95.38	60.39	35.00	258.32	5348	3806.61	891.15	354.56	24.28	186.17	17.71	3.75	0.80
		SD	546.69	17.74	18.77	5.39	34.55	960	777.68	214.19	63.57	11.82	63.60	4.57	0.96	0.16
	T2	Mean	1854.45	97.94	63.28	34.66	263.89	5466	3868.90	894.83	365.73	28.00	188.02	17.79	3.98	0.88
		SD	552.25	15.40	15.42	4.60	28.99	885	753.64	210.38	63.39	12.38	55.32	4.06	0.90	0.16
	T3	Mean	1939.86	94.25	58.68	35.56	280.29	5514	3656.29	817.86	353.71	26.50	178.39	17.42	3.81	0.94
		SD	532.56	15.87	16.83	4.66	34.85	875	815.12	206.02	61.59	12.65	62.68	4.27	1.00	0.18
		P value	0.010	0.133	0.018	0.142	<0.001	0.196	0.009	<0.001	0.179	0.008	0.095	0.446	0.056	<0.001

DP: Dietary pattern, SD: Standard deviation
T: tertile as T1 is the lowest tertile and T3 is the highest tertile
ANOVA for normally, and Kruskal-Wallis test for non-normally distributed data

Gender	DP3		Total Energy (kcal)	Protein (g)	Animal Protein (g)	Plant Protein (g)	Carbohydrate (g)	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)	Vitamin D (µg)	Vitamin C (mg)	Total Fiber (g)	n-3 fatty acid (g)	PUFA/SAFA ratio
Men	T1	Mean	2267.77	79.97	44.89	35.08	288.92	5010	2951.51	668.27	303.44	18.13	126.75	14.54	3.05	1.01
		SD	579.73	17.20	17.52	5.71	44.09	954	786.63	224.62	62.92	11.87	54.14	4.21	0.98	0.27
	T2	Mean	2072.36	86.50	52.49	34.01	260.22	5190	3378.95	759.74	325.18	20.83	157.58	15.83	3.51	0.91
		SD	601.08	13.58	14.22	5.66	34.34	954	685.60	169.66	55.33	10.19	55.24	3.93	0.84	0.21
	T3	Mean	2396.85	92.21	58.56	33.64	234.51	5705	3512.46	820.72	342.49	23.39	160.10	16.34	3.79	0.91
		SD	592.39	21.73	21.96	6.57	42.07	1135	912.33	255.46	76.96	14.34	63.03	4.55	1.19	0.23
		P value	<0.001	<0.001	<0.001	0.023	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Women	T1	Mean	2008.21	91.70	56.31	35.39	284.16	5250	3548.15	817.86	342.69	25.03	169.92	16.75	3.60	0.90
		SD	510.03	16.15	17.22	5.03	34.40	883	798.01	211.69	62.45	13.07	62.06	4.31	0.99	0.19
	T2	Mean	1891.95	94.86	60.05	34.81	266.19	5311	3780.35	864.78	355.26	25.37	184.34	17.65	3.85	0.86
		SD	543.58	14.26	14.76	4.61	28.89	839	718.41	196.60	57.49	12.08	56.88	3.89	0.91	0.16
	T3	Mean	1913.92	100.99	65.97	35.02	252.18	5767	4002.37	920.94	375.98	28.37	198.29	18.52	4.10	0.86
		SD	581.08	17.40	17.97	5.07	31.33	917	778.17	218.16	64.60	11.69	60.02	4.52	0.92	0.18
		P value	0.073	<0.001	<0.001	0.543	<0.001	<0.001	<0.001	<0.001	<0.001	0.008	<0.001	<0.001	<0.001	0.143

DP: Dietary pattern, SD: Standard deviation
T: tertile as T1 is the lowest tertile and T3 is the highest tertile
ANOVA for normally, and Kruskal-Wallis test for non-normally distributed data

	Japanese diet score		Total Energy (kcal)	Protein (g)	Animal Protein (g)	Plant Protein (g)	Carbohydrate (g)	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)	Vitamin D (µg)	Vitamin C (mg)	Total Fiber (g)	n-3 fatty acid (g)	PUFA/SAFA ration
Men	0-2	Mean	1940.99	77.28	44.79	32.48	268.16	4881	2742.12	629.46	279.49	16.04	116.84	12.88	3.00	0.92
		SD	535.51	14.11	14.21	5.43	44.57	914	649.72	182.25	48.74	7.39	48.58	3.12	0.81	0.25
	3-4	Mean	2219.48	85.53	51.11	34.42	260.59	5283	3261.49	742.13	320.59	19.50	147.77	15.56	3.43	0.93
		SD	516.09	16.00	17.30	5.80	44.34	966	669.03	184.15	53.35	11.79	51.62	3.66	0.98	0.21
	5-7	Mean	2597.92	96.67	60.82	35.86	254.33	5778	3877.53	887.34	375.46	27.65	181.35	18.45	3.96	0.99
		SD	592.62	20.31	21.86	6.44	48.55	1124	822.12	249.94	66.96	14.35	62.02	4.37	1.15	0.27
		P value	<0.001	<0.001	<0.001	<0.001	0.047	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005
Women	0-4	Mean	1711.17	89.94	56.32	33.61	269.95	5219.99	3413.08	794.12	326.75	22.52	162.19	15.64	3.55	0.84
		SD	453.72	12.75	14.15	4.35	31.64	812.20	589.99	179.44	45.68	9.80	47.12	2.89	0.79	0.16
	5	Mean	1974.65	96.85	60.73	36.12	268.11	5477.67	3940.61	904.96	372.20	25.94	193.19	18.66	3.83	0.89
		SD	455.09	12.37	13.98	4.78	30.73	856.64	637.60	199.97	48.30	10.89	54.39	3.67	0.81	0.18
	6-7	Mean	2298.42	105.18	68.33	36.85	263.18	5801.04	4284.07	967.03	401.35	32.81	215.65	20.37	4.37	0.92
		SD	555.02	19.77	20.92	5.15	40.06	987.40	854.24	228.01	68.24	14.46	69.75	4.94	1.10	0.19
		P value	<0.001	<0.001	<0.001	<0.001	0.217	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

DP: Dietary pattern, SD: Standard deviation
T: tertile as T1 is the lowest tertile and T3 is the highest tertile
ANOVA for normally, and Kruskal-Wallis test for non-normally distributed data

Appendix 5. Mean daily intake (g) of selected food groups by dietary pattern

Gender	DP1		Fish	Soybean and soybean products	Vegetables	Fruits
Men	T1	Mean	78.3	64.3	190.8	69.4
		SD	53.6	38.8	79.2	56.9
	T2	Mean	94.0	84.5	307.4	115.3
		SD	50.4	44.6	79.7	62.8
	T3	Mean	114.4	101.9	471.4	142.0
		SD	57.6	53.3	120.8	573.6
		P value	0.001	0.001	0.001	0.001
Women	T1	Mean	100.6	72.4	261.1	114.6
		SD	47.7	34.1	71.9	59.5
	T2	Mean	122.7	91.8	358.5	145.8
		SD	50.5	38.0	68.1	73.9
	T3	Mean	135.8	110.2	526.0	176.9
		SD	59.6	48.0	135.0	77.3
		P value	0.001	0.001	0.001	0.001

DP: Dietary pattern, SD: Standard deviation
T: tertile as T1 is the lowest tertile and T3 is the highest tertile
ANOVA for normally, and Kruskal-Wallis test for non-normally distributed data

Gender	DP2		Fish	Soybean and soybean products	Vegetables	Fruits
Men	T1	Mean	88.3	79.3	346.3	121.6
		SD	52.5	49.8	150.8	73.8
	T2	Mean	103.7	87.7	340.1	118.4
		SD	54.0	43.9	146.5	67.2
	T3	Mean	94.6	83.7	283.6	86.7
		SD	59.9	51.0	143.8	67.9
		P value	0.014	0.049	<0.001	<0.001
Women	T1	Mean	110.8	89.2	388.8	149.9
		SD	55.3	43.7	158.4	77.2
	T2	Mean	126.5	93.1	385.1	148.1
		SD	53.4	43.0	132.7	71.0
	T3	Mean	121.9	92.1	371.0	139.1
		SD	54.6	43.2	145.7	76.5
		P value	0.003	0.651	0.387	0.189

DP: Dietary pattern, SD: Standard deviation
T: tertile as T1 is the lowest tertile and T3 is the highest tertile
ANOVA for normally, and Kruskal-Wallis test for non-normally distributed data

Gender	DP3		Fish	Soybean and soybean products	Vegetables	Fruits
Men	T1	Mean	82.3	80.5	282.4	89.3
		SD	52.9	48.9	139.8	65.8
	T2	Mean	97.1	81.9	330.7	119.9
		SD	47.7	43.1	129.0	69.5
	T3	Mean	107.2	88.4	356.7	117.4
		SD	63.2	52.6	168.2	74.8
		P value	<0.001	0.229	<0.001	<0.001
Women	T1	Mean	112.3	91.6	353.7	131.2
		SD	55.7	45.6	144.3	71.4
	T2	Mean	116.2	90.7	385.2	147.2
		SD	52.1	40.9	136.0	74.1
	T3	Mean	130.6	92.0	406.1	158.8
		SD	54.9	43.3	153.0	77.1
		P value	0.005	0.948	<0.001	0.001

DP: Dietary pattern, SD: Standard deviation
T: tertile as T1 is the lowest tertile and T3 is the highest tertile
ANOVA for normally, and Kruskal-Wallis test for non-normally distributed data

Gender	Japanese diet score		Fish	Soybean and soybean products	Vegetables	Fruits
Men	0-2	Mean	75.0	62.0	238.7	79.7
		SD	34.8	40.9	120.3	60.4
	3-4	Mean	90.8	84.4	330.6	108.8
		SD	54.6	46.6	130.0	67.1
	5-7	Mean	124.5	105.7	404.2	140.4
		SD	63.0	48.3	157.3	74.8
		P value	0.001	0.001	0.001	0.001
Women	0-4	Mean	102.6	76.2	328.1	125.0
		SD	43.4	39.0	115.4	66.0
	5	Mean	117.4	101.6	414.8	155.0
		SD	45.2	41.5	134.2	77.6
	6-7	Mean	150.1	110.4	449.9	175.3
		SD	64.3	41.9	165.0	76.6
		P value	0.001	0.001	0.001	0.001

DP: Dietary pattern, SD: Standard deviation
T: tertile as T1 is the lowest tertile and T3 is the highest tertile
ANOVA for normally, and Kruskal-Wallis test for non-normally distributed data

Appendix 6. Association between Dietary patterns and prevalence of low muscle strength stratified by gender

	Men			Women		
	OR	(95%CI)	*P* value	OR	(95%CI)	*P* value
DP1						
T1	3.03	(1.25-7.36)	0.015	2.30	(1.00-5.30)	0.051
T2	1.35	(0.49-3.71)	0.567	1.48	(0.63-3.51)	0.371
T3 (reference)	1			1		
DP2						
T1	1.12	(0.47-2.67)	0.805	1.69	(0.71-4.03)	0.233
T2	1.19	(0.51-2.80)	0.687	1.86	(0.80-4.32)	0.151
T3 (reference)	1			1		
DP3						
T1	0.97	(0.36-2.62)	0.949	0.54	(0.22-1.32)	0.175
T2	2.07	(0.84-5.12)	0.115	1.30	(0.62-2.73)	0.493
T3 (reference)	1			1		
Japanese diet score						
Low	5.05	(1.60-16.0)	0.006	3.65	(1.38-9.68)	0.009
Medium	3.04	(1.01-9.15)	0.048	1.12	(0.37-3.42)	0.845
High (reference)	1			1		

Note:
DP: Dietary pattern, OR: Odd ration, CI: Confidence interval
T: tertile as T1 is the lowest tertile and T3 is the highest tertile
Adjusted for economic circumstance, living alone, BMI, energy intake, multimorbidity, physical activity