Interaction of Eating Status and Dietary Variety on Incident Functional Disability among Older Japanese Adults

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Abstract

OBJECTIVES: To examine whether eating status and dietary variety were associated with functional disability during a 5-year follow-up analysis of older adults living in a Japanese metropolitan area.
DESIGN: A 5-year follow-up study.
SETTING: Ota City, Tokyo, Japan.
PARTICIPANTS: A total of 10,308 community-dwelling non-disabled adults aged 65–84 years.
MEASUREMENTS: Eating status was assessed using a self-reported questionnaire. Dietary variety was assessed using the dietary variety score (DVS). Based on the responses, participants were classified according to eating alone or together and DVS categories (low: 0–3; high: 4–10). Functional disability incidence was prospectively identified using the long-term care insurance system's nationally unified database. Multilevel survival analyses calculated the adjusted hazard ratio (HR) and 95% confidence interval (CI) for incident functional disability.
RESULTS: During a 5-year follow-up, 1,991 (19.3%) individuals had functional disabilities. Eating status or DVS were not independently associated with incident functional disability. However, interaction terms between eating status and DVS were associated with functional disability; HR (95% CI) for eating together and low DVS was 1.00 (0.90–1.11), eating alone and high DVS was 0.95 (0.77–1.17), and eating alone and low DVS was 1.20 (1.02–1.42), compared to those with eating together and high DVS.
CONCLUSION: Older adults should avoid eating alone or increase dietary variety to prevent functional disability. This can be ensured by providing an environment of eating together or food provision services for eating a variety of foods in the community.

Key words: Eating alone, eating status, dietary variety, functional disability.

Introduction

Japan is one of the world's most rapidly aging countries. It is estimated that 35% of Japan's population will comprise individuals aged 65 years and above by 2040, which makes it important to control the increase in the number of people requiring long-term care and to extend healthy life expectancy (1). The aging of society leads to a rise in the number of people livin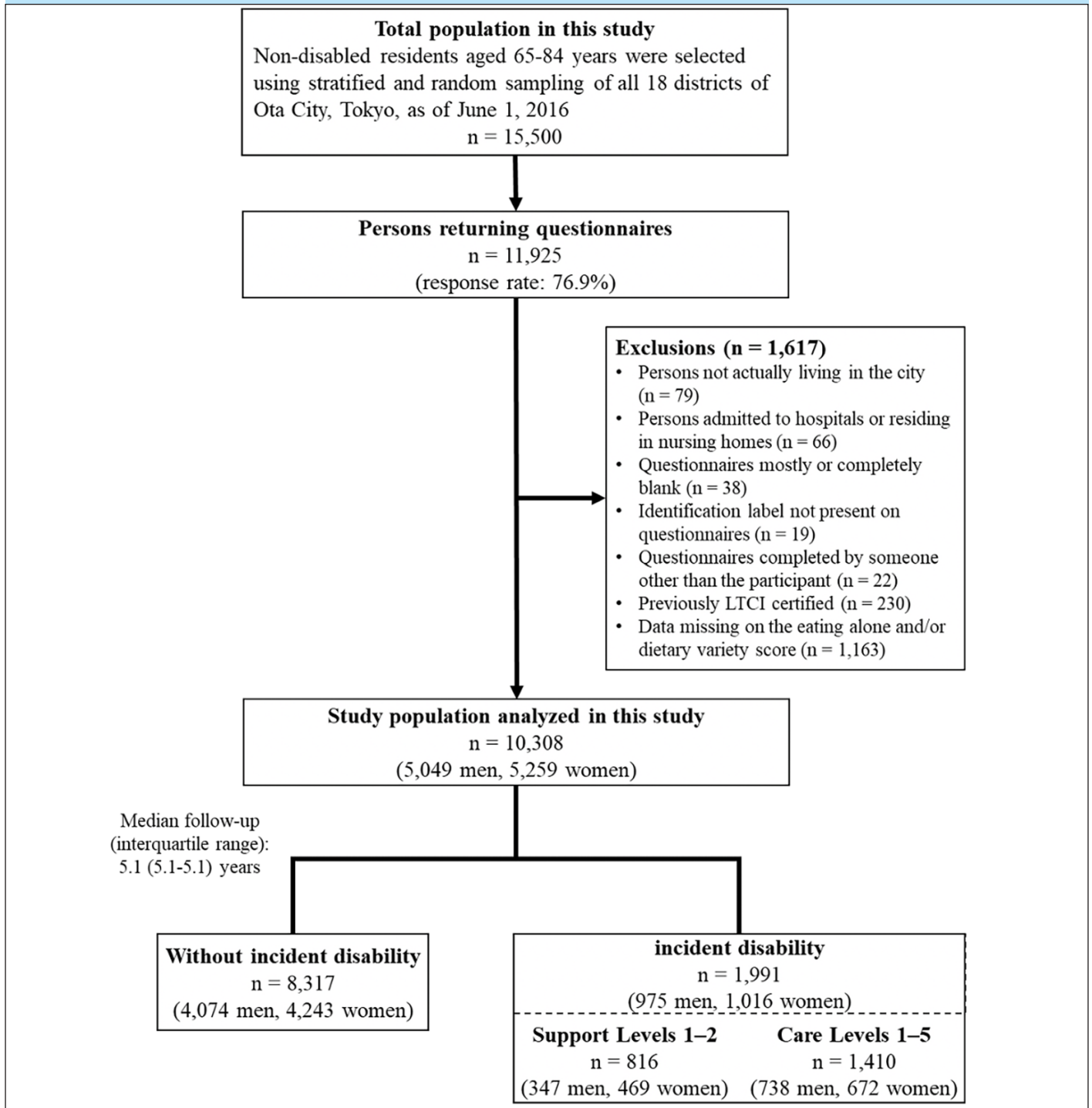g alone (1). Especially in Japanese metropolitan areas, it is estimated that about 30% of older people will live alone, and about 45% of elderly households will comprise single members by 2040. Living alone has been reported to be associated with the risk of malnutrition (2) and can lead to increased long-term care status and mortality (3).

These demographic trends are likely to increase the frequency of eating alone among older adults (4). Eating alone has been identified as one of the risk factors for malnutrition associated with eating behavior (5), reducing dietary variety (6, 7), nutrition intake (8), and appetite (9). Several studies have indicated that eating alone is associated with depression (6, 10, 11) and mortality among older men living with others (12). Reduced social networks and social support after losing a spouse or peers and friends among older adults can lead them to eat alone. However, maintaining functional social support networks in old age is associated with healthy dietary behaviors (5). In other words, preventing social isolation and eating together are important for maintaining healthy eating behaviors and health status among older adults.

Over the last few years, several dietary guidelines have recommended consuming a variety of foods (13, 14) customized to fit unique local dietary cultures (e.g., Healthy Eating Index, Mediterranean diet, Dietary Approach to Stop Hypertension, and Japanese Diet Index). Many of these dietary patterns have been reported to be beneficial for middle-aged and older adults (15-18). In Japan, a simple indicator used to assess dietary variety is the dietary variety score (DVS) (19). A higher DVS has been positively associated with physical function (20, 21) and reduced depression (22).

Many studies have examined the individual associations between eating status and dietary variety with health status and physical function, respectively. Since eating alone has been shown to reduce dietary variety (6, 7), the association between dietary variety and health outcomes may differ depending on eating status. However, no studies have yet investigated the interactive association between eating status and dietary variety in cases of functional disability among older adults. To bridge this gap in the literature, this study examines the combined impacts of eating alone and dietary variety on incident functional disability among older adults living in a metropolitan area of Japan.

Figure 1. Flow diagram of study participants

Total population in this study
Non-disabled residents aged 65-84 years were selected using stratified and random sampling of all 18 districts of Ota City, Tokyo, as of June 1, 2016
n = 15,500

Persons returning questionnaires
n = 11,925
(response rate: 76.9%)

Exclusions (n = 1,617)
- Persons not actually living in the city (n = 79)
- Persons admitted to hospitals or residing in nursing homes (n = 66)
- Questionnaires mostly or completely blank (n = 38)
- Identification label not present on questionnaires (n = 19)
- Questionnaires completed by someone other than the participant (n = 22)
- Previously LTCI certified (n = 230)
- Data missing on the eating alone and/or dietary variety score (n = 1,163)

Study population analyzed in this study
n = 10,308
(5,049 men, 5,259 women)

Median follow-up (interquartile range): 5.1 (5.1-5.1) years

Without incident disability
n = 8,317
(4,074 men, 4,243 women)

incident disability
n = 1,991
(975 men, 1,016 women)

Support Levels 1–2	Care Levels 1–5
n = 816	n = 1,410
(347 men, 469 women)	(738 men, 672 women)

LTCI: long-term care insurance

Methods

Study population

Study data were obtained from a community-wide intervention study on preventing frailty, launched in 2016 in Ota City, Tokyo, Japan (23, 24). A total of 15,500 residents who did not have long-term care insurance (LTCI) certification (25), aged 65–84 years, stratified by sex and age group (65–74 and 75–84 years), were selected using random sampling strategies in all 18 districts of the city (23). In July 2016, 15,500 self-administered questionnaires were distributed, out of which 11,925 were returned (response rate: 76.9%). Finally, 10,308 questionnaires (5,049 men and 5,259 women) that had no missing eating status, dietary variety, and incident functional disability items and did not match the exclusion criteria were included in the present analysis (Figure 1).

The study protocol was developed in accordance with the guidelines proposed in the Declaration of Helsinki and was approved by the ethics committee of the Tokyo Metropolitan Institute of Gerontology. All the participants gave their informed consent before participation.

Measurements

Eating status

The eating status of participants was assessed using the question: "Who do you usually have meals with?" Multiple response choices were as follows: "only yourself," "spouse," "children," "children's spouse," "parents," "spouse's parents," "grandchildren/great-grandchildren," "friends," and "others" (10). Responses of eating alone ("only yourself") or eating together (anything but "only yourself") were focused on in this study.

Dietary variety

Dietary variety was assessed using the DVS (19). The DVS comprises 10 food groups (meat, fish/shellfish, eggs, milk, soybean products, green/yellow vegetables, potatoes, fruit, seaweed, and fats/oils). Respondents were asked to choose from the following four options: "almost daily," "once every two days," "once or twice a week," and "almost never." For the DVS, 1 point was given only when a respondent chose "almost daily," and 0 was given for all other items, and the total score was computed. The total score ranged from 0 to 10; higher scores indicated greater dietary variety. Previous studies have reported that DVS ≤3 is associated with a higher risk of decline in muscle mass and physical function and a higher risk of depression (21, 22). In this study, 0–3 points were considered low, and 4–10 points were considered high.

Functional disability

Functional disability was defined by the LTCI certification, which employs a nationally standardized, multistep assessment of elderly health (25). All citizens aged 40 years and above in Japan pay premiums and are covered by the system, and all citizens aged 65 years and above are eligible for formal caregiving services (25). To receive caregiving services through the LTCI system, an individual must be certified according to the national uniform standards (25). The Municipal Certification Committee of Needed Long-Term Care (comprising physicians, nurses, and health and social service experts) decides whether an older adult should be certified as requiring long-term care and classifies care needs under one of seven levels (Support Levels 1–2; Care Levels 1–5). The LTCI certification levels are defined from Support Level 1 (i.e., "limited in instrumental activities of daily living [ADL] but independent in basic ADL") to Care Level 5 (i.e., "requiring care in all ADL tasks"). Functional disability was defined as the onset of long-term care needs at Support Level 1 or above, using the date of LTCI application as the date of disability

incident. Moreover, we classified the onset of Support Levels 1–2 or Care Levels 1–5 to examine low disability levels and incident severe disability. For the purpose of this study, July 1, 2021, was considered the endpoint.

Covariates

The covariates in this study were age, sex, living situation (living with others or alone), education level (presence or absence of ≥college/vocational), equivalent income (presence or absence of ≥2.5 million yen/year), body mass index (BMI; thinness: <21.5 kg/m², obesity: ≥25 kg/m²), heart disease, stroke, diabetes mellitus, cancer, bone/joint disease, smoking status (current, never, or former), exercise habits, social isolation, and depressive mood. Equivalent income was calculated by dividing household income by the square root of the number of household members (26). BMI was defined as self-rated body weight (kg) divided by self-rated height squared (m²), which was divided into thinness (<21.5) and obesity (≥25.0) (27). Exercise habits were defined as more frequently than once per week. Social isolation was defined as face-to-face or non-face-to-face contact with individuals outside the household less frequently than once per week (28-30). Depressive mood was defined as a score of ≥2 on the 5-item Geriatric Depression Scale. (31, 32).

Statistical analysis

Data were analyzed using Stata 17.0 (StataCorp, TX, USA). An α value of <0.05 indicated statistical significance. DVS and age were analyzed using the Shapiro-Wilk test to confirm the data's normality. To examine the continuous variables associated with eating alone and DVS, one-way ANOVA was used. Similarly, chi-square test was conducted for categorical variables. The impact of the two individual factors—eating status and DVS—on incident disability risk was assessed. As the current data had a multilevel structure comprising individuals (at Level 1) nested within 18 districts (at Level 2), multilevel survival analyses with fixed slopes and random intercept models were conducted—calculating the adjusted hazard ratio (HR) and 95% confidence interval (CI) for incident disability, Support Levels, or Care Levels. Eating status and DVS were simultaneously included as fixed factors, and the district was considered as a random factor. Two analytical models were constructed. Model 1 was adjusted for age and sex, and Model 2 included all covariates. Multicollinearity was checked by using the tolerance and variance inflation factors (VIF).

The combination categories of the fixed factors, eating status and DVS (reference as eating together and high DVS), were analyzed. We conducted secondary and stratified analyses. First, regarding the possible influence of reverse causation, sensitivity analyses were performed using the same statistical approach, after excluding individuals who developed a functional disability by the second year of follow-up. Second, regarding the possible influence of a potential dose-response relationship with DVS, sensitivity analyses were performed using the same

Table 1. Characteristics of study participants, according to eating status and DVS

variables	All (N = 10308)	Eating together and high DVS (n = 3632, 35.2%)	Eating together and low DVS (n = 5074, 49.2%)	Eating alone and high DVS (n = 547, 5.3%)	Eating alone and low DVS (n = 1055, 10.2%)	P-value
DVS, mean (SD)	3.2(2.2)	5.4(1.5)	1.7(1.1)	5.4(1.5)	1.4(1.1)	<0.001
Age (years), mean (SD)	74.0(5.4)	74.4(5.4)	73.5(5.4)	75.5(5.3)	73.6(5.5)	<0.001
Sex (women), n (%)	5259(51.0)	2170(59.8)	2291(45.2)	359(65.6)	439(41.6)	<0.001
Living alone (presence), n (%)	2022(19.6)	377(10.4)	548 (10.8)	396 (72.4)	701(66.5)	<0.001
Marital status, n (%)						<0.001
Married	6878(66.7)	2785(76.7)	3812(75.1)	86(15.7)	195(18.5)	
Widowed or divorced	2533(24.6)	669(18.4)	965(19.0)	332(60.7)	567(53.7)	
Never married	720(7.0)	126(3.5)	209(4.1)	117(21.4)	268(25.4)	
Education level (≥Junior college/vocational college), n (%)	3671(35.6)	1581(43.5)	1661(32.7)	183(33.5)	246(23.3)	<0.001
Equivalent income (≥2.5 million yen), n (%)	3969(38.5)	1827(50.3)	2171(42.8)	203(37.1)	334(31.7)	<0.001
Body mass index (kg/m²), mean (SD)	22.7(3.1)	22.4(3.1)	22.9(3.1)	22.0(2.8)	23.0(3.3)	<0.001
<21.5 (thinness), n (%)	3720(36.1)	1459(40.2)	1668(32.9)	236(43.1)	357(33.8)	<0.001
≥25 (obesity), n (%)	2159(21.0)	660(18.2)	1155(22.8)	78(14.3)	266(25.2)	<0.001
Heart disease (presence), n (%)	2149(20.9)	705(19.4)	1121(22.1)	91(16.6)	232(22.0)	<0.001
Stroke (presence), n (%)	716(7.0)	227(6.3)	380(7.5)	22(4.0)	87(8.3)	0.001
Diabetes mellitus (presence), n (%)	1827(17.7)	592(16.3)	954(18.8)	76(13.9)	205(19.4)	<0.001
Cancer (presence), n (%)	1620(15.7)	565(15.6)	796(15.7)	89(16.3)	170(16.1)	0.829
Bone/joint disease (presence), n (%)	3113(30.2)	1169(32.2)	1487(29.3)	174(31.8)	283(26.8)	0.007
Smoking status (current), n (%)	1271(12.3)	234(6.4)	739(14.6)	46(8.4)	252(23.9)	<0.001
Exercise habits (presence), n (%)	7570(73.4)	2939(80.9)	3544(69.9)	425(77.7)	662(62.8)	<0.001
Social isolation (presence), n (%)	3243(31.5)	888(24.5)	1731(34.1)	164(30.0)	460(43.6)	<0.001
Depressive mood (presence), n (%)	3289(31.9)	927(25.5)	1647(32.5)	192(35.1)	523(49.6)	<0.001

DVS: dietary variety score; SD: standard deviation.

statistical approach, using DVS as a continuous variable. Third, since living situation is thought to influence eating status, stratified analyses were performed using the same statistical approach by living situation.

Participants with missing information regarding their disability, eating status, and DVS were excluded from the analysis. The missing covariates were assigned to the "missing" category and included in the analysis to reduce selection bias.

Results

During a median follow-up of 5.1 (interquartile range: 5.1–5.1) years, a total of 1,991 (19.3%; 975 men and 1016 women) participants presented with disabilities, with rates of 43.4 per 1000 person-years, and 787 (39.5%; 394 men and 393 women) presented with a disability during the first two years. When we categorized the low disability levels and incident severe disability, 816 participants were certified as Support Levels 1–2 and 1,410 participants were certified as Care Levels 1–5 during the follow-up period. Additionally, 319 (39.1%) and 586 (41.6%) were certified during the first two years, respectively.

Table 1 shows the baseline characteristics of the study population based on eating status and DVS. There were significant differences between groups in terms of age, sex, living situation, marital status, education level, equivalent income, BMI, the prevalence of heart disease, stroke, diabetes mellitus, bone/joint disease, smoking status, exercise habits, social isolation, and depressive mood.

Table 2 indicates the independent associations of eating status and DVS with incident disability. Eating alone (HR, 1.11; 95%CI, 0.97–1.27) and low DVS (HR, 1.04; 95%CI, 0.95–1.15) were not significantly independently associated with incident disability. Similarly, eating status and DVS were not significantly independently associated with the certification of Support Levels or Care Levels.

Table 3 indicates the combined associations of eating status and DVS with incident disability. Compared with people eating together and high DVS, disability risk was significantly higher among participants eating alone and low DVS (HR, 1.20; 95% CI, 1.02–1.42), but not in eating together and low DVS (HR, 1.00; 95% CI, 0.90–1.11) or eating alone and high DVS (HR, 0.95; 95% CI, 0.77–1.17). Similar results were found at the Support Levels and Care Levels.

Supplementary Tables S1, S2, S3, and S4 indicate the results of the sensitivity and stratified analyses. Although sensitivity and stratified analyses showed that the results did

Table 2. Multilevel survival analyses of independent associations of each eating status and DVS with incident disability (N = 10308)

Variables included simultaneously in the same model	Number of events/participants	Incidence rate per 1000 person-years	Model 1			Model 2		
			HR	(95% CI)	P-Value	HR	(95% CI)	P-Value
Support or Care Levels								
Eating status								
Eating together	1614/8706	41.3	1.00	(Ref.)		1.00	(Ref.)	
Eating alone	377/1602	55.2	1.24	(1.11-1.39)	<0.001	1.11	(0.97-1.27)	0.141
Dietary variety								
High DVS	805/4179	42.9	1.00	(Ref.)		1.00	(Ref.)	
Low DVS	1186/6129	43.7	1.15	(1.05-1.26)	0.003	1.04	(0.95-1.15)	0.385
All	1991/10308	43.4						
Support Levels 1–2								
Eating status								
Eating together	666/8706	17.0	1.00	(Ref.)		1.00	(Ref.)	
Eating alone	150/1602	22.0	1.17	(0.98-1.39)	0.092	1.14	(0.92-1.42)	0.222
Dietary variety								
High DVS	328/4179	17.5	1.00	(Ref.)		1.00	(Ref.)	
Low DVS	488/6129	18.0	1.20	(1.04-1.39)	0.011	1.14	(0.98-1.32)	0.081
All	816/10308	17.8						
Care Levels 1–5								
Eating status								
Eating together	1125/8706	27.8	1.00	(Ref.)		1.00	(Ref.)	
Eating alone	285/1602	40.0	1.36	(1.19-1.55)	<0.001	1.15	(0.98-1.35)	0.095
Dietary variety								
High DVS	574/4179	29.5	1.00	(Ref.)		1.00	(Ref.)	
Low DVS	836/6129	29.6	1.10	(0.99-1.23)	0.071	0.97	(0.87-1.09)	0.634
All	1410/10308	29.6						

DVS: dietary variety score, CI: confidence interval, HR: hazard ratio; Model 1: Adjusted for age and sex; Model 2: Adjusted for variables in Model 1 plus living situation, material status, education level, equivalent income, thinness, obesity, heart disease, stroke; diabetes mellitus, cancer, bone/joint disease, smoking status, exercise habits, social isolation, and depressive mood.

not substantially differ from those of primary analyses, the significance of the effect of increased risk of Care Levels by DVS disappeared in additional analysis using DVS as a continuous variable (Supplementary Table S3). Furthermore, eating alone attenuated the effects of the reduced risk of functional disability by high DVS for those who were living together (Supplementary Table S4).

Discussion

This study examined whether eating status and dietary variety were associated with functional disability during 5-year follow-up analysis of older adults living in a Japanese metropolitan area. The results indicated that eating status and dietary variety were not independently associated with functional disability. However, there was an interaction between eating status and dietary variety showing that eating alone and low DVS increased the risk of functional disability when compared to eating together and high DVS. Therefore, it is pertinent for the elderly to either avoid eating alone or eat a variety of foods to reduce the risk of functional disability.

The interaction term between eating status and dietary variety was statistically significant, which suggests that eating together or eating a variety of foods may be important in reducing the risk of functional disability. Compared with eating together and high DVS, eating alone and low DVS increased the risk of functional disability, but satisfying either can reduce the increased risk. It is a fact that living alone is an important factor responsible for eating alone among older adults. Eating alone could manifest because of an imbalance in lifestyle rhythms, such as mealtimes between family members and poor family relationships (33). The present study showed a trend that increased the risk associated with high DVS combined with eating alone among those living together, compared to those with both high DVS and eating together. Hence, promoting and providing opportunities within the family and community to eat together is necessary. A previous study showed that eating alone was associated with poor food shopping assistance and/or not receiving any food from neighbors or relatives (34). Social support is important not only for eating alone but also for dietary variety, as poor social support and economic disadvantage, as well as frailty, are associated with reduced

Table 3. Multilevel survival analyses of associations of combination of eating status and DVS with incident disability (N = 10308)

Combination categories	Numver of events/participants	Incidence rate per 1000 person-years	Model 1			Model 2		
			HR	(95% CI)	P-Value	HR	(95% CI)	P-Value
Support or Care Levels								
Eating together and high DVS	688/3632	42.0	1.00	(Ref.)		1.00	(Ref.)	
Eating together and low DVS	926/5074	40.8	1.09	(0.99-1.21)	0.082	1.00	(0.90-1.11)	0.972
Eating alone and high DVS	117/547	49.5	1.02	(0.84-1.24)	0.827	0.95	(0.77-1.17)	0.627
Eating alone and low DVS	260/1055	58.2	1.50	(1.30-1.73)	<0.001	1.20	(1.02-1.42)	0.032
All	1991/10308	43.4						
Support Levels 1–2								
Eating together and high DVS	281/3632	17.1	1.00	(Ref.)		1.00	(Ref.)	
Eating together and low DVS	385/5074	17.0	1.15	(0.98-1.34)	0.080	1.09	(0.93-1.28)	0.266
Eating alone and high DVS	47/547	19.9	0.98	(0.72-1.34)	0.898	0.97	(0.69-1.37)	0.879
Eating alone and low DVS	103/1055	23.1	1.47	(1.17-1.85)	0.001	1.36	(1.04-1.76)	0.023
All	816/10308	17.8						
Care Levels 1–5								
Eating together and high DVS	488/3632	28.8	1.00	(Ref.)		1.00	(Ref.)	
Eating together and low DVS	637/5074	27.0	1.03	(0.92-1.16)	0.595	0.94	(0.83-1.06)	0.323
Eating alone and high DVS	86/547	35.0	1.07	(0.85-1.35)	0.546	0.99	(0.77-1.27)	0.934
Eating alone and low DVS	199/1055	42.6	1.59	(1.35-1.88)	<0.001	1.26	(1.04-1.53)	0.020
All	1410/10308	29.6						

DVS: dietary variety score, CI: confidence interval, HR: hazard ratio; Model 1: Adjusted for age and sex; Model 2: Adjusted for variables in Model 1 plus living situation, material status, education level, equivalent income, thinness, obesity; heart disease, stroke, diabetes mellitus, cancer, bone/joint disease, smoking status, exercise habits, social isolation, and depressive mood.

dietary variety (35). However, these services and community measures are not widespread or sufficiently advanced in the community. Enhancing these services would be important to reduce the risk of functional disability.

However, the independent association between eating status and disability identified in this study is not consistent with that in previous studies, which have shown that older men living with others and eating alone have an increased risk of mortality (12), and eating alone has been associated with nutritional risk (5), poor appetite (9), and depression (6, 10, 11). In this study, the relationship between eating alone and functional disability was nullified by adjusting for physical function, lifestyle, and depression, thus suggesting that these variables may mediate the association between eating alone and disability.

Similarly, dietary variety was not independently associated with disability, which is also not consistent with the findings of previous studies. Several studies have indicated that dietary variety reduces all-cause and cancer mortality (36, 37), and the Japanese dietary pattern is associated with a lower risk of disability (17, 18). While these studies have assessed dietary variety and Japanese dietary pattern using detailed dietary records or food frequency questionnaires, the DVS was calculated based on the weekly frequency of intake from 10 food groups (19). Therefore, it is likely that no association was found due to the underestimation of the effect of dietary intake. Moreover, the median (interquartile range) of the DVS in this study was 3 (1-5), and about 60% of the participants were classified in the category of low DVS. Although DVS cut-off scores in this study were set based on previous studies

(21, 22), it may be necessary to set cut-off scores according to the specific study population or the methods of data acquisition because DVS from self-administered mail survey data (23, 38) is typically reported as lower than those obtained from health check-up data. (19, 21, 22)

Limitations & Strength

Although this study reveals important findings, it has several limitations. First, the self-administered questionnaire used in this study may have involved recall bias. DVS from self-administered questionnaires may be underestimated compared to face-to-face interview surveys (19, 21-23, 38), and this underestimation could have attenuated its association with the outcome variables. Second, the presence of confounding variables such as cognitive status and meal delivery services that were not measured cannot be completely ruled out and could overestimate the results. Nevertheless, since this survey excluded residents who have LTCI certification, it is thought that the impact on the quality of the answers would be minimized. Third, the DVS was calculated based on the intake frequency of 10 food groups, which is not comparable to actual dietary intake. However, previous studies indicate that a higher DVS was associated with a higher intake of protein and micronutrients (39), and since protein intake increased as DVS increased with an intervention program (40). Therefore, the DVS might indicate a limited understanding of dietary intake. Fourth, an older adult in Japan must contact the municipal government to officially certify his or her care

needs (25). Some disabled individuals might have failed to report themselves, resulting in the underestimation of disability incidence (detection bias). The associations between eating status and DVS with an incident disability may also have been underestimated in this study because of a decrease in new LTCI applications during the coronavirus disease (COVID-19) pandemic (41). Finally, it should be noted that this study employed data sources from a community-wide intervention study. The DVS in the intervention subgroup improved at the population level (24). This study only assessed the baseline eating habits of participants and was unable to record subsequent changes in eating habits during the follow-up. If eating habits improved during follow-up, the relationship between eating habits and functional disability risk, as identified in this study, may have been underestimated.

Despite these limitations, to the best of our knowledge, this is the first study among Japanese older adults wherein eating together or increased dietary variety was found to reduce the risk of functional disability during a 5-year follow-up period.

Conclusion

Although eating status and dietary variety were not independently associated with functional disability, interactions between eating status and dietary variety reduced the risk of functional disability. Therefore, it is important for older adults to avoid eating alone or to eat a variety of foods. This can be ensured by providing an environment of eating together or food provision services for eating a variety of foods in the community.

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