Preventive Medicine 149 (2021) 106613

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Community social networks, individual social participation and dietary behavior among older Japanese adults: Examining mediation using nonlinear structural equation models for three-wave longitudinal data

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ARTICLE INFO

Keywords:
Living arrangements
Health disparities
Cross-lagged panel model
Social support

ABSTRACT

Community social networks positively affect older adults' dietary behavior, but the underlying mechanisms remain uncertain. This study investigated if the relationship between community social networks and dietary behavior is mediated by social participation, and whether the influence of community social networks differs across sociodemographic groups. We conducted a cross-lagged panel mediation analysis employing nonlinear structural equation modeling using panel data from the Japan Gerontological Evaluation Study (JAGES), a longitudinal study of Japanese older adults in 2010, 2013, and 2016, which included 11,347 men and 14,105 women aged over 65. Monodirectional relationships in community social networks, individual social participation, and fruit/vegetable intake were examined. Community social networks were associated with social participation regardless of sociodemographic conditions. Individual social participation was in turn, positively associated with fruit/vegetable intake, with this association being stronger among those living alone. Analyses further showed that individuals' social participation positively mediated the relationship between community social networks and fruit/vegetable intake. For both genders, the mediating effects were stronger among people living alone than in those living with someone. However, community networks could also directly and negatively affect fruit/vegetable intake among men who live alone unless they participated in community activities. Community social networks may promote social participation, thereby facilitating healthier dietary behavior regardless of sociodemographic status. Social participation in turn may positively contribute to the dietary health of people living alone. Community-based interventions to encourage people living alone to participate in social activities may help reduce inequality in dietary behavior related to cohabitation status.

1. Introduction

As population aging is advancing worldwide, the maintenance of the physical, mental, and social capabilities of older adults has become an important target of public health interventions. Maintaining access to services for the proper intake of nutrients is essential (World Health Organization, 2002a), especially in sociodemographically disadvantaged older adults, including those living in poverty and those living alone. Previous research has reported that these adults eat less nutritionally balanced daily meals, and have a lower intake of dietary fiber, fruit, and vegetables (Conklin et al., 2014; Fukuda et al., 2017; Giskes et al., 2010).

Social participation of older adults should be a primary target of policies focused on healthy aging, as it is one of the three key dimensions of human functioning in the International Classification of Functioning, Disability and Health (ICF). Moreover, social participation is known to boost the overall health of older adults via altering various health behaviors (World Health Organization, 2002b). For older adults, social

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https://doi.org/10.1016/j.ypmed.2021.106613
Received 8 December 2020; Received in revised form 6 April 2021; Accepted 9 May 2021
Available online 11 May 2021

participation is associated with good dietary behaviors (Levasseur et al., 2010; Saito et al., 2019; World Health Organization et al., 2002), good mental health (Takagi et al., 2013a, 2013b), mortality (Glass et al., 1999; Holt-Lunstad et al., 2010; Hsu, 2007), and well-maintained physical function (Kanamori et al., 2014).

Fostering community social networks can serve as an effective community-based intervention to promote social participation and health behavior in older adults. Living in a community that has a solid interpersonal connection positively affects the health of older individuals (Nakagomi et al., 2019; Tsuji et al., 2018). Samuel et al. (2015) also suggest that social cohesion is associated with higher probability of consuming at least five daily fruits/vegetable servings. Based on social capital theory, community contextual characteristics that strengthen social cohesion may affect individuals' health and health behavior via social contagion, informal social control, and collective efficacy (Kawachi and Berkman, 2014). Theoretically, the collective efficacy mechanism positively affects the behaviors of older adults, even those disconnected from other residents. For example, a neighborhood with successful social networks makes lobbying for improved neighborhood environments easy (Kawachi and Berkman, 2014) and can affect all residents' behaviors. On the other hand, the effects through the mechanisms of social contagion and informal social control may be mediated somewhat by individual residents' own social networking. Given that social contagion refers to social influences, norms, and learning that affect individuals' behaviors through connected peers (Christakis and Fowler, 2007; Christakis and Fowler, 2008; Kohler et al., 2001), it is even more evident when individuals participate in a well-established community social network. Unhealthy behaviors are incompatible with informal social control, which, in terms of criminology, is an intervention done by neighborhood residents among deviant people (Kawachi and Berkman, 2014). Among acquaintances, however, it could well be a subject of control, care, and support (Umberson et al., 2010). Here again, the key is each individual's social participation that can explain some of the effects of community-level social networks on individual behaviors.

Community social networks, or the structural aspect of social capital, provide more opportunities for social participation and encourage residents to participate in activities, thereby increasing their social ties. This participation also instills norms conducive to healthier behaviors (Umberson et al., 2010). Particularly in Japan, such norms are more likely to encourage people to change their behavior. Several studies suggest that for middle- and older-aged Japanese, the social pressure to conform is one of the determinants of their behavioral changes (Murayama et al., 2019; Tanaka et al., 2016). Although individual social networking is known to be associated with higher fruit/vegetable intake (Emmons et al., 2007; Lindstrom et al., 2001), evidence as to what extent the effects of community-level social networking are mediated by individual-level social networking and how the effects differ among sociodemographic groups have been insufficient.

The purpose of this study was to investigate the mechanism through which community social networks affect nutritional intake and whether the effect differs between those who are socially vulnerable and those who are not. Accordingly, we hypothesized that (1) individual social participation mediates the relationship between community social networks and nutritional intakes; however, (2) the magnitude of these mediating effects varies between those who are sociodemographically vulnerable and those who are not.

This study investigated fruit/vegetable intake as an indicator of nutritional intake, because it is regarded as the most important diet in preventing age-related disease (Hung et al., 2004; Nicklett and Kadell, 2013) and has been the target of dietary guidance for older adults in Japan's national health promotion campaigns (Kenko-nippon 21 Planning Study Group, 2000; Next Kenko-nippon 21 Planning Study Group, 2014).

2. Methods

2.1. Data

We used three waves of panel data from the years 2010, 2013, and 2016 of the Japan Gerontological Evaluation Study (JAGES) Project, which is an ongoing nationwide survey of community-dwelling older adults in Japan (Kondo et al., 2018). Baseline information was collected in 2010 through self-reporting questionnaires mailed to 95,827 individuals in 16 municipalities. Random sampling was conducted in 10 large municipalities, while all eligible residents in the remaining six small municipalities received the questionnaire. A total of 62,418 participants gave valid data (overall response rate: 65.1%; in large municipalities: 65.8.%; and in small municipalities: 64.4%). A follow-up survey was conducted in 2013 and 2016. Using the encrypted insured number, 54,529 participants were linked to the follow-up survey data. In this study, the criterion for exclusion was non-participation in either follow-up surveys (n = 29,077). The remaining respondents who had completed the questionnaires in all three waves (n = 25,452) were extracted as study participants (Fig. 1).

The JAGES protocol was approved by the Ethical Committee at the National Center for Geriatrics and Gerontology (approval no. 992) and Chiba University (approval no. 2493). Return of the questionnaire was interpreted as informed consent.

2.2. Measurements

2.2.1. Nutritional intake

We defined the frequency of participants' fruit/vegetable intake as an index of nutritional intake. The choices given were *twice a day or more*, *once a day*, *four to six times a week*, *two to three times a week*, *once a week*, *less than once a week*, and *none*. We dichotomized the variables into *once a day or more* and *less than once a day* for a healthy frequency of fruit/vegetable intake, because several studies suggested that such frequent intake is associated with reduced risk of mortality and cardiovascular disease of middle/older Japanese adults (Nagura et al., 2009; Sauvaget et al., 2003; Takachi et al., 2007). Specifically, Sauvaget et al. (2003) suggest that daily vegetable intake is associated with reduced risk of deadly stroke by 26% in both men and women, compared with an intake of once or less per week through a prospective cohort study of 40,349 Japanese within an 18-year follow-up, and that daily consumption of fruits is associated with a 35% reduction in overall stroke risk in men

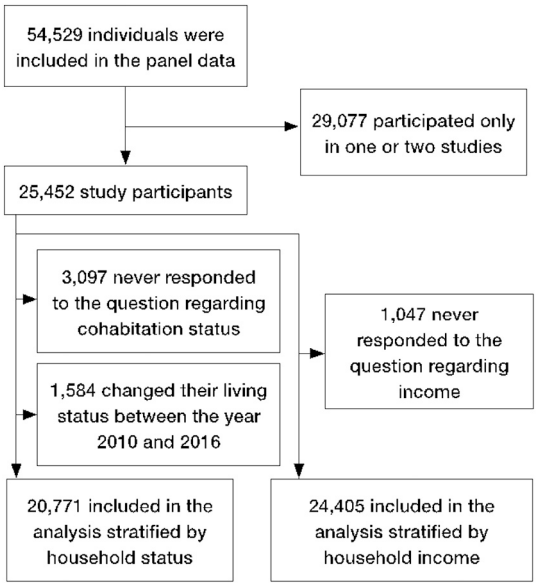

Fig. 1. Flow of selecting participants in each stratifies analysis.

and a 25% reduction in women.

2.2.2. Individual social participation and community social networks

We assumed that communities with many group activity participants have rich community social networks. We measured levels of community social networks using the proportion of community activity participants as a proxy measure. We assessed respondents' participation in five community activities: volunteer, sports, hobby, senior citizen club, and neighborhood association with six choices: *four or more times a week*, *two or three times per week*, *once a week*, *one to three times a month*, *a few times a year*, and *never*. First, we defined individuals' social participation as a binary variable of *at least once a week in at least one group or organization*. Using this definition, the proportion of residents who participated in social activities once a week or more at the elementary school district level was used as the surrogate variable of the community social network (0–1 continuous variable).

Per methods employed in previous sociological and social epidemiologic studies (Fujiwara et al., 2017; Takagi et al., 2013a, 2013b), we used school districts as the community unit. Municipalities, the smallest formal administrative units in Japan, contain multiple school districts that usually represent former villages and in which people share many cultural events, ceremonies, and other social activities, making them an adequate unit for evaluating community social networks.

2.2.3. Living alone

Respondents were asked about their cohabitation status—living alone or with someone. In the first wave, the question was *Who do you live with?* with choices: *I live alone*, *spouse*, *children*, *spouses of children*, *grandchildren or great-grandchildren*, *parents*, *parents-in-law*, *brothers or sisters*, *brothers/sisters-in-law*, *other relatives*, *unrelated person/people*, and *other*. Multiple answers were allowed. In the second and third waves, the subjects were asked, *Which of the following best describes your family composition?* The response options in the second wave were: *I live alone*, *I live with my family* (including two-family homes), and *other* (e.g., institution). In the third wave, the response options were, *I live alone*, *I live with my spouse, who is 65 or older*, *I live with my spouse, who is younger than 65*, *I live with my son/daughter* (two-family household), and *other* (e.g., three-family household). Respondents who answered *I live alone* in all three waves were identified as living alone, while those who chose anything else in all three waves were considered to be living with someone. We also excluded samples of respondents who changed their cohabitation status during the six-year follow-up period. This study categorizes people living alone as socially vulnerable, while living with someone as not vulnerable.

2.2.4. Income

Equivalized family income was calculated by dividing the respondents' six-year average of midpoints for the fifteen categories of annual household income (shown below) by the square root of the number of people living together. We excluded those who had never reported their average income in the three waves. The income categories were as follows: less than 0.5, 0.5–1.0, 1.0–1.5, 1.5–2.0, 2.0–2.5, 2.5–3.0, 3.0–4.0, 4.0–5.0, 5.0–6.0, 6.0–7.0, 7.0–8.0, 8.0–9.0, 9.0–10.0, 10.0–12.0, and over 12.0 million Japanese yen (JPY). We categorized respondents as higher-income and lower-income using the median as the threshold (2.83 million yen). Similar to the variable for living status, people with lower family incomes were operationally classified as socially vulnerable, and others as not.

2.3. Statistical analysis

Nonlinear structural equation models (SEMs) were employed to examine monodirectional relationships among community social networks in 2010, individual social participation in 2013, and the frequency of fruit/vegetable intake in 2016 within a framework of cross-lagged panel analysis (Selig and Preacher, 2009) (Supplementary appendix A.1). Unlike traditional regression models, SEMs simultaneously assess all relevant modelled pathways as either independent and/or dependent factors. Linear models were fitted for community social networks (proportion between 0 and 1) and probit models were fitted for individual social participation and the frequency of intake (both variables were dichotomized according to previous subsections). We obtained 95% confidence intervals (CIs) from 1000point estimates from bootstrapped resamples. In order to interpret the impact of the estimated probit regression coefficients as absolute risk difference (RD), the estimates were converted to predicted values at 10% increased intervened levels, with the mean of independent variables substituted (details are shown in supplementary appendix B.1). As a structural equation modeling technique, the mediating effect, the sequential pathways leading from community social networks in 2010 to individual social participation in 2013, and fruit/vegetable intake in 2016 were calculated by the product of the coefficients in probit regressions for each path. The proportion mediated by the mediator variable is the ratio of the mediating effect to the total effect, which details the amount of total effect that operates through the mediator variable. The total effect was the sum of all the direct and indirect effects of community social networks in 2010 on fruit/vegetable intake in 2016.

All models were fitted through the weighted least squares option in Mplus software (Asparouhov and Muth'en, 2010). Missing data were handled by full-information maximum likelihood, that is, a method of imputing the missing values using all the individual's variables that are not lacking, based on the principle of the maximum likelihood method.

The model fit was assessed based on chi square, the root mean square error of approximation, comparative fit index, and standardized root mean square residuals. We conducted this three-wave cross-lagged mediation analysis by gender and social vulnerability invariance (strata defined by living status and equivalent family income). For a robustness check, we conducted a series of sensitivity analyses with an alternative social participation cut-off (once a month) and with other covariates selections—age, education, employment status, depression, instrumental activities of daily living (IADL), and subjective sense of health.

We used STATA version 15.1 (StataCorp, College Station, TX, USA) for descriptive analysis, along with Mplus version 8.2 (Muthen & Muthen, Los Angeles, CA, USA) to fit SEMs.

3. Results

We excluded 29,077 of the 54,529 participants in the baseline survey because they had not participated in the follow-up studies. We then used the remaining 25,452 subjects for our analysis. For an analysis stratified by household status and household income, we identified 20,771 subjects (9765 male and 11,006 female) for the former and 24,405 subjects (11,147 male and 13,258 female) for the latter (Fig. 1).

A descriptive analysis showed that approximately 30% of men and 40% of women participated in social activities once a week or more (Table 1). Women living with someone tended to participate less in social activities than those living alone. This trend was consistent for all three waves. Around 70% of men and 80% of women were found to eat fruit and/or vegetables once a day or more. The average (standard deviation) social participation at the school district level was 37.4% ([SD = 0.77]) in wave 1, 36.0% ([SD = 0.73]) in wave 2, and 41.1% ([SD = 0.82]) in wave 3.

We obtained good model fits for our structural equations (Supplementary Appendix C.1). Probit structural equation models showed that individual social participation mediated the relationship between community social networks and fruit/vegetable intake (among men: mediating effects = 0.009, 95% CI [0.004, 0.015]; among women: mediating effect = 0.008, 95% CI [0.004, 0.0014]) (Table 2). The mediating effects of community social networks on fruit/vegetable intake via individual social participation were greater among people living alone than among those living with someone for both men and women (among men living alone: mediating effect = 0.040, 95% CI

Table 1
Descriptive statistics

	Men									
	Overall (n = 11,347)		Household status (N = 9765)				Household income (N = 11,147)			
			Living Alone (n = 613)		Living with someone (n = 9152)		Low family income (n = 4565)		High family income (n = 6582)	
Individual variables	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Social participation										
Frequency of social participation (2010)										
≧1 per week	3542	31.2	180	29.4	2932	32.0	1180	25.9	2317	35.2
<1 per week	6163	54.3	333	54.3	4982	54.4	2556	56.0	3518	53.5
Missing	1642	14.5	100	16.3	1238	13.5	829	18.2	747	11.4
Frequency of social participation (2013)										
≧1 per week	3261	28.7	155	25.3	2697	29.5	1111	24.3	2104	32.0
<1 per week	6719	59.2	383	62.5	5419	59.2	2798	61.3	3820	58.0
Missing	1367	12.1	75	12.2	1036	11.3	656	14.4	658	10.0
Frequency of social participation (2016)										
≧1 per week	3333	29.4	161	26.3	2749	30.0	1171	25.7	2119	32.2
<1 per week	5959	52.5	341	55.6	4867	53.2	2364	51.8	3516	53.4
Missing	2055	18.1	111	18.1	1536	16.8	1030	22.6	947	14.4
Nutritional intake										
Frequency of fruit/vegetable intake (2010)										
Once or more/day	17,722	70.5	338	55.1	6830	74.6	3114	68.2	5020	76.3
Other	5943	23.6	240	39.2	1840	20.1	1185	26.0	1229	18.7
Missing	1477	5.9	35	5.7	482	5.3	266	5.8	333	5.1
Frequency of fruit/vegetable intake (2013)										
Once or more/day	12,624	73.4	355	57.9	7042	76.9	3143	68.9	5226	79.4
Other	4272	24.8	244	39.8	1995	21.8	1346	29.5	1284	19.5
Missing	308	1.8	14	2.3	115	1.3	76	1.7	72	1.1
Frequency of fruit/vegetable intake (2016)										
Once or more/day	9349	74.3	353	57.6	7053	77.1	3157	69.2	5211	79.2
Other	3030	24.1	249	40.6	1982	21.7	1317	28.9	1292	19.6
Missing	197	1.6	11	1.8	117	1.3	91	2.0	79	1.2

	Women									
	Overall (n = 14,105)		Household status (N = 11,006)				Household income (N = 13,258)			
			Living Alone (n = 1896)		Living with someone (n = 9110)		Low family income (n = 6518)		High family income (n = 6740)	
Individual variables	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Social participation										
Frequency of social participation (2010)										
≧1 per week	5246	37.2	769	40.6	3450	37.9	2081	31.9	2913	43.2
<1 per week	5884	41.7	709	37.4	3891	42.7	2833	43.5	2777	41.2
Missing	2975	21.1	418	22.1	1769	19.4	1604	24.6	1050	15.6
Frequency of social participation (2013)										
≧1 per week	5129	36.4	771	40.7	3351	36.8	2083	32.0	2812	41.7
<1 per week	6547	46.4	790	41.7	4339	47.6	3136	48.1	3057	45.4
Missing	2429	17.2	335	17.7	1420	15.6	1299	19.9	871	12.9
Frequency of social participation (2016)										
≧1 per week	5022	35.6	731	38.6	3293	36.2	1993	30.6	2808	41.7
<1 per week	5660	40.1	739	39.0	3817	41.9	2665	40.9	2725	40.4
Missing	3423	24.3	426	22.5	2000	22.0	1860	28.5	1207	17.9
Nutritional intake										
Frequency of fruit/vegetable intake (2010)										
Once or more/day	23,293	79.3	1500	79.1	7637	83.8	5116	78.5	5852	86.8
Other	4537	15.4	281	14.8	1052	11.6	1090	16.7	559	8.3
Missing	1557	5.3	115	6.1	421	4.6	312	4.8	329	4.9
Frequency of fruit/vegetable intake (2013)										
Once or more/day	16,931	83.5	1597	84.2	7925	87.0	5336	81.9	6074	90.1
Other	3018	14.9	277	14.6	1076	11.8	1100	16.9	591	8.8
Missing	339	1.7	22	1.2	109	1.2	82	1.3	75	1.1
Frequency of fruit/vegetable intake (2016)										
Once or more/day	13,084	84.5	1570	82.8	7876	86.5	5276	81.0	6050	89.8
Other	2149	13.9	299	15.8	1105	12.1	1125	17.3	607	9.0
Missing	258	1.7	27	1.4	129	1.4	117	1.8	83	1.2
Neighborhood variable			*Mean*	*SD*						
Social participation rate (%)[a]										

(*continued on next page*)

Table 1 (*continued*)

In the year of 2010	37.38	0.77
In the year of 2013	35.99	0.73
In the year of 2016	41.10	0.82

[a] The proportion of residents participating social activities more than once a week

Table 2
The path-specific direct effect, mediating effect, and total effects represented by estimated coefficients in the probit models for cross-lagged panel analysis

	Men						Women					
	Coef.	Bootstrap 95% CI					Coef.	Bootstrap 95% CI				
Overall sample												
Path-specific direct effect	−0.014	[	−0.100	,	0.070	]	0.083	[	0.000	,	0.166	]
Mediating effect	0.009	[	0.004	,	0.015	]	0.008	[	0.004	,	0.014	]
Total effect	0.052	[	0.008	,	0.098	]	0.084	[	0.040	,	0.128	]
Mediating effect / Total effect (%)	–						10%					
Stratified by household status												
Living alone												
Path-specific direct effect	−0.559	[	−1.154	,	−0.169	]	0.079	[	−0.130	,	0.304	]
Mediating effect	0.040	[	−0.014	,	0.127	]	0.023	[	0.007	,	0.052	]
Total effect	−0.177	[	−0.392	,	0.030	]	−0.020	[	−0.133	,	0.100	]
Mediating effect / Total effect (%)	–						–					
Living with someone												
Path-specific direct effect	0.034	[	−0.051	,	0.134	]	0.108	[	0.003	,	0.206	]
Mediating effect	0.006	[	0.002	,	0.013	]	0.006	[	0.001	,	0.014	]
Total effect	0.082	[	0.031	,	0.127	]	0.123	[	0.072	,	0.183	]
Mediating effect / Total effect (%)	7%						5%					
Stratified by household income												
Lower family income												
Path-specific direct effect	0.028	[	−0.107	,	0.151	]	0.095	[	−0.027	,	0.209	]
Mediating effect	0.006	[	0.000	,	0.015	]	0.012	[	0.004	,	0.021	]
Total effect	0.030	[	−0.039	,	0.101	]	0.068	[	0.005	,	0.134	]
Mediating effect / Total effect (%)	20%						18%					
Higher family income												
Path-specific direct effect	−0.041	[	−0.154	,	0.079	]	0.032	[	−0.089	,	0.161	]
Mediating effect	0.009	[	0.003	,	0.018	]	0.002	[	−0.003	,	0.009	]
Total effect	0.041	[	−0.015	,	0.107	]	0.071	[	0.003	,	0.145	]
Mediating effect / Total effect (%)	–						3%					

Note 1: Path-specific direct effect refers to the probit coefficient of the relationship between community social networks in 2010 and nutritional intakes in 2016 (Fig. 2 and 3, and βxy in supplementary appendix B.1).
Note 2: Mediating effect indicates the effect of community social networks in 2010 on nutritional intakes in 2016 via individual social participation in 2013. This was calculated by the product of each probit coefficients (β_xm1*β_my2 in supplementary appendix B.1).
Note 3: Coef. Denotes coefficient, and CI denotes confidence intervals. In the case that either path-specific direct effect, total effect or mediating effect has a minus sign, the mediating effect / total effect (%) was not calculated.

[−0.014, 0.127]; men living with someone: mediating effect = 0.006, 95% CI [0.002, 0.013]; women living alone: mediating effect = 0.023, 95% CI [0.007, 0.052]; and women living with someone: mediating effect = 0.006, 95% CI [0.001, 0.014]) (Table 2).

The positive association between individual social participation and fruit/vegetable intake was also stronger among those living alone (men living alone: risk difference [RD] =13.5%; men living with someone: RD = 1.9%; women living alone: RD = 2.9%; and women living with someone: RD = 1.3%) (Fig. 2). However, the cross-level association between community social networks and individual social participation was similar regardless of cohabitation status (among men living alone: RD = 0.2%; men living with someone: RD = 0.3%; women living alone: RD = 0.5%; and women living with someone: RD = 0.4%) (Fig. 2).

Community social networks might have a favorable effect on nutritional intake among men living alone, but they negatively affect those who do not participate in social activities (path-specific direct effect = −0.559, 95% CI [−1.154, −0.169], RD = -2.2%) (Fig. 2). In terms of stratification by household income, there was no coherent difference in statistical significance between the low-income and high-income groups (Fig. 3). The path diagrams stratified only by gender are shown in the supplementary appendix D.1.

The sensitivity analysis using an alternative social participation cut-off (once a month) exhibited similar results (Appendix E.1). Likewise, a sensitivity analysis adding covariates showed similar results with slightly smaller coefficients. However, the covariate-adjusted estimates were not obtained in a few of the bootstrapped samples, indicating a relatively poor fit of the models with covariates.

4. Discussion

The key findings of this study are threefold. First, individual social participation in part mediates the temporal association between community social networks and fruit/vegetable intake. Second, despite the small effect size (RD = 0.2–0.5%), community social networks may encourage residents to participate in social activities regardless of income level and cohabitation status. Third, the association between individuals' social participation and subsequent fruit/vegetable intake is greater among people living alone than among those living with someone. These main findings support our hypothesis that individual social participation mediates the relationship between community social networks and health behavior among older Japanese adults. The magnitude of the mediating effects varies depending on participants' social background.

In the Netherlands, Waverijn et al. revealed that self-management of chronic illness played a mediating role between community social capital and self-rated health among people suffering persistently from a

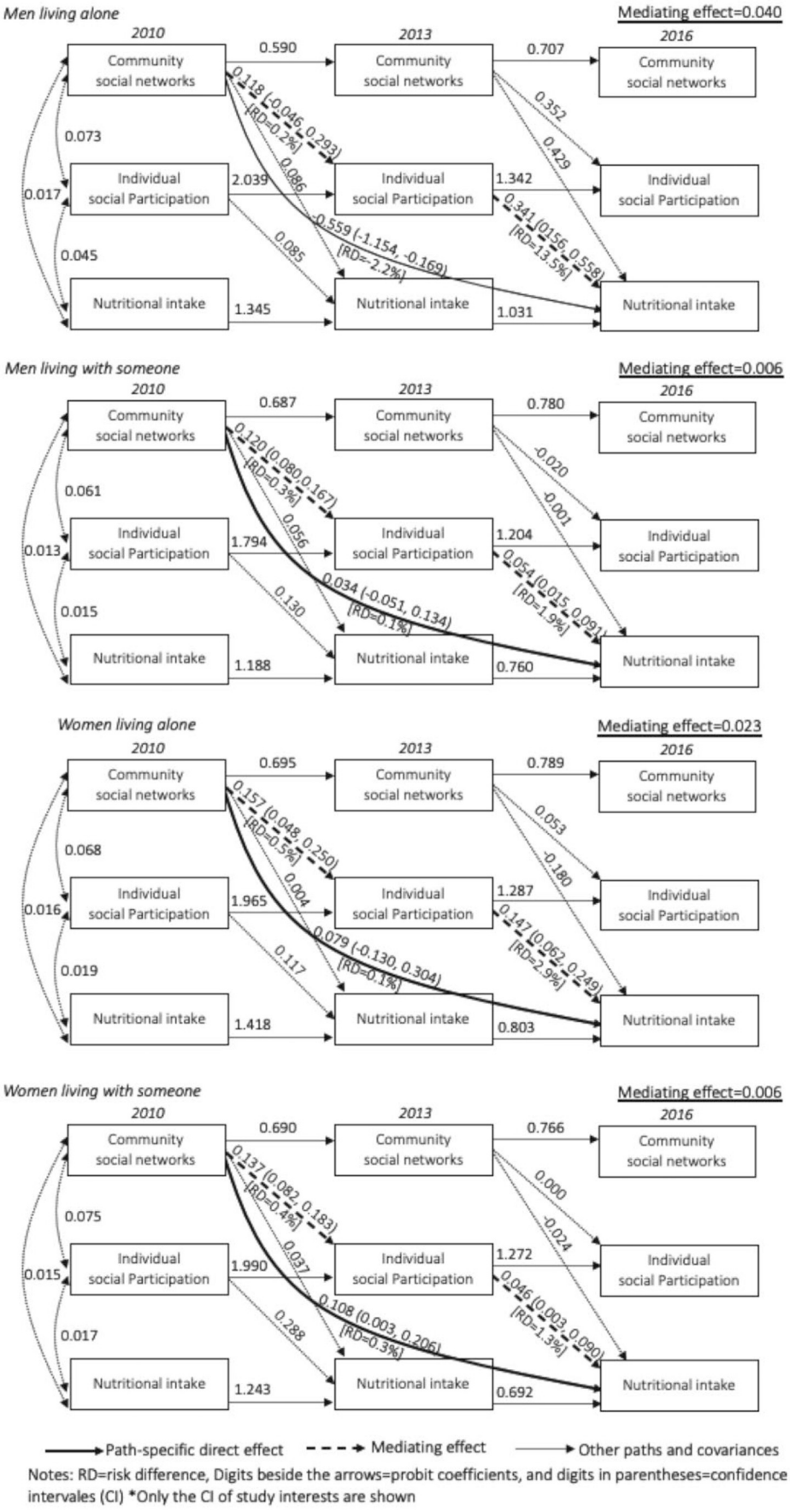

Fig. 2. Path diagrams – startification by household status.

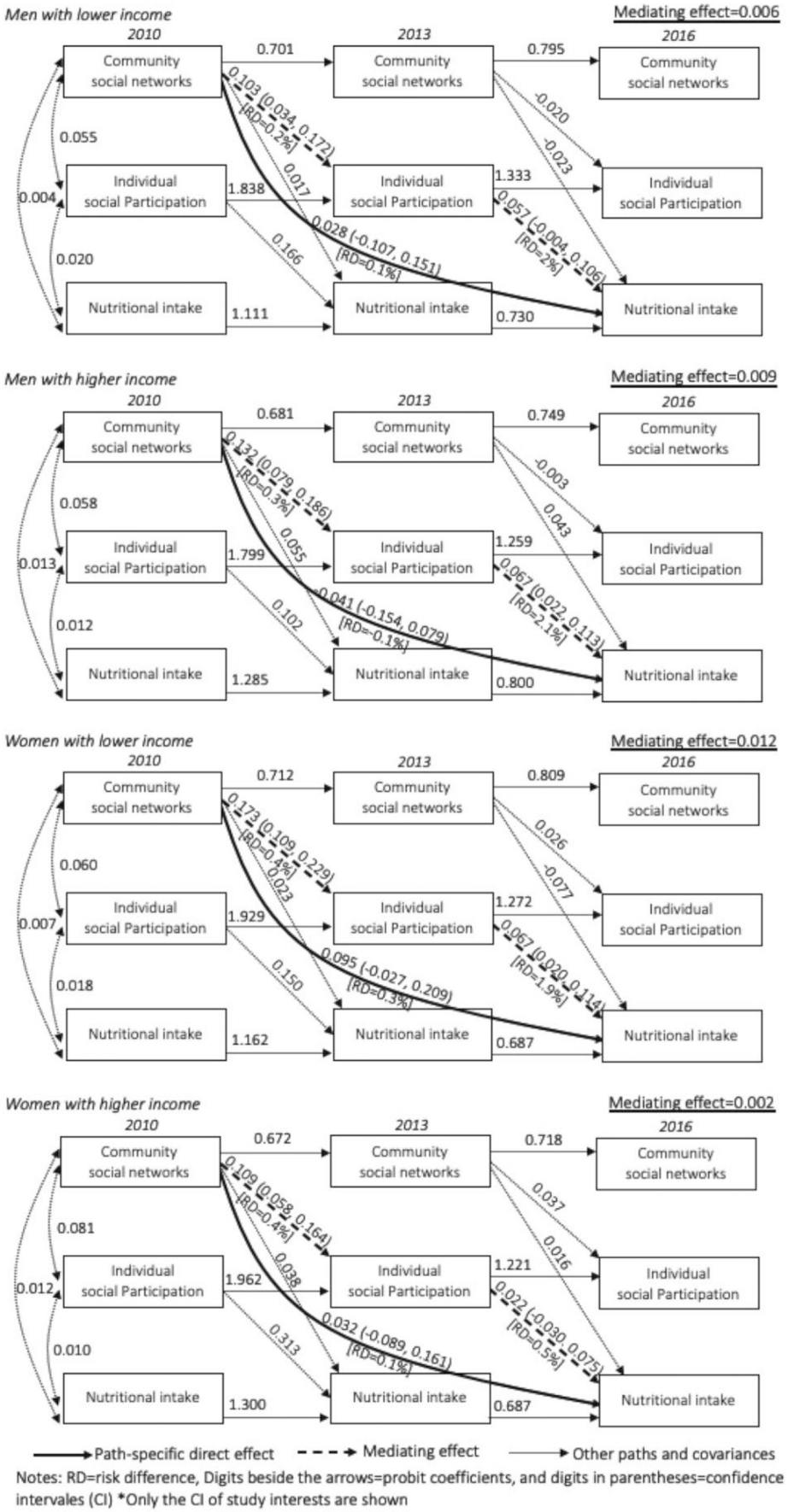

Fig. 3. Path diagrams – startification by household status.

disease and mild physical disabilities (29.7% mediated through chronic illness self-management) (Waverijn et al., 2016). The present study adds new findings that individual social participation plays a mediating factor linking community social networks and individuals' nutritional intake. Our study also indicates that community social networks positively affect individuals' social participation in all sociodemographic groups. The exception is men living alone, which shows a statistically non-significant association. One possible explanation for this might be the small sample size ($n = 613$). Another reason could be their smaller social networks and fewer channels of social support. Among the Japanese older population, men tend to have fewer close relationships with the people "with whom it was hard to imagine life without" than women (Antonucci et al., 2002). Considering that, in general, men tend to rely on the social support of their spouses (Antonucci and Akiyama, 1987), men living alone could face difficulties in social participation.

Our study suggests that the nutritional intake of people living alone increases if they participate in social activities. This can be attributed to the small baseline fruit/vegetable consumption of men living alone (57.6%) against men living with someone (77.1%), whereas for women, these were 82.8% and 86.5%, respectively. Another potential reason is that individual social participation compensates for the lack of family ties that would otherwise encourage such people to eat fruit/vegetable. Persons living with someone benefit from healthy environments and cohabitation social norms (Umberson, 1987) like smoking cessation (Takagi et al., 2014). Nonetheless, participating in social activities could buffer the detrimental effects of living alone through alternative social support or a healthy diet.

In addition, community social networks positively affect the nutritional intake of men living alone when they participate in community group activities. Interestingly, however, failure to participate in such activities adversely affects them. This may be a drawback inherent to cohesive communities that maintain a strong sense of solidarity, dissociating anyone outside the circle (Portes, 1998). People who do not participate in community activities may thus be excluded from the circle, hindering them from developing healthy behavioral norms (Amemiya et al., 2019).

Regarding the link between community social networks and nutritional intake, we did not find any explicit differences associated with income level. One possible reason may be that a healthy diet is available inside a rich social network regardless of income. Predicting older people's health solely by their income is difficult, so taking their wealth into account may help future research (Krieger et al., 1997; Smith and Kington, 1997).

Our study has several strengths. First, to the best of our knowledge, this is the first study to demonstrate the possible mechanisms of the relationship between community social networks and health behaviors. Second, we utilized large population-based panel data, which enabled us to make a conditional causal inference by adopting a cross-lagged panel model. Nonetheless, this study should be carefully interpreted. The complexity of statistical modeling made minimizing the variables inevitable. We were thus unable to consider potential confounding factors, including participants' sociability or health status. In addition, we excluded participants who did not respond to one or more of the three waves or who changed their cohabitation status due to divorce or bereavement. These people, on the other hand, may be more socially isolated and participate less in social activities, thus underestimating the results.

Furthermore, our outcome measure, a single question regarding fruit/vegetable intake, may not accurately reflect individuals' nutritional quality due to lack of information about servings, consumption of other foods, and their balances. In particular, this study could only consider one aspect of individuals' nutritional quality, despite that animal protein and dairy intake are also important for older people (Yamaguchi et al., 2018). Further research is needed to identify the possible mechanisms of the relationship between community social networks and comprehensive health behaviors, including protein and dairy intakes. In addition, all the data used were self-reported. Although some studies have suggested that self-reported measurements are comparable to objective measurements (Hesseldenz, 1976), they may be susceptible to measurement bias. Finally, each estimate was small in every stratification. However, the results are especially important in public health intervention because socio-environmental factors, including community social networks, affect every resident and eventually amplify the attributable impact.

5. Conclusion

These results of our analysis support the effectiveness of community organizing interventions on health promotion, especially in promoting healthy diets (Haseda et al., 2019). Encouraging people living alone to participate in social activities may reduce health behavioral inequalities related to cohabitation status.

Funding

This work was supported by Grant-in-Aid for Scientific Research (15H01972, 15H04781, 15H05059, 15K03417, 15K03982, 15K16181, 15K17232, 15K18174, 15K19241, 15K21266, 15KT0007, 15KT0097, 16H05556, 16K09122, 16K00913, 16K02025, 16K12964, 16K13443, 16K16295, 16K16595, 16K16633, 16K17256, 16K17281, 16K19247, 16K19267, 16K21461, 16K21465, 16KT0014, 17K04305,17K34567, 17K04306, 25253052, 25713027, 26285138, 26460828, 26780328, 18H03018, 18H04071, 18H03047, 18H00953, 18H00955, 18KK0057, 19H03901, 19H03915, 19H03860, 19K04785, 19K10641,19K11657,19K19818, 19K19455, 19K24060, 19K20909) from JSPS (Japan Society for the Promotion of Science); Health Labour Sciences Research Grants (H26-Choju-Ippan-006, H27-Ninchisyou-Ippan-001 H28- Choju-Ippan-002, H28- Ninchisyou-Ippan-002, H29-Chikyukibo-Ippan-001, H30-Jyunkankinado-Ippan-004, 18H04071, 19FA1012, 19FA2001, 21FA1012) , Research project on health and welfare promotion for the elderly from the Ministry of Health, Labour and Welfare, Japan; the Research and Development Grants for Longevity Science from Japan Agency for Medical Research and development (AMED) (JP17dk0110027, JP18dk0110027, JP18ls0110002, JP18le0110009, JP19dk0110034, JP19dk0110037, JP20lk0310073, 20dk0110037h0002, 21dk0110037h0003); the Research Funding for Longevity Sciences from National Center for Geriatrics and Gerontology (24–17, 24–23, 29–42, 30–30, 30–22, 20-19, 21-20); Open Innovation Platform with Enterprises, Research Institute and Academia (OPERA, JPMJOP1831) from the Japan Science and Technology (JST); a grant from The Japan Foundation For Aging And Health (J09KF00804); a grant from Innovative Research Program on Suicide Countermeasures(1–4); a grant from Sasakawa Sports Foundation; a grant from Japan Health Promotion & Fitness Foundation; a grant from Chiba Foundation for Health Promotion & Disease Prevention,

the 8020 Research Grant for fiscal 2019 from the 8020 Promotion Foundation (adopted number: 19–2-06); a grant from Niimi University (1915010); grants from Meiji Yasuda Life Foundation of Health and Welfare. The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the respective funding organizations.

Author statement

M Nishio was responsible for the study design, analysis and interpretation of data, as well as the drafting of the article. D Takagi supported M Nishio in study design, analysis, interpretation of data and revising manuscript. T Shinozaki intensively helped the design and analysis of the study as well as revising the manuscript. N Kondo gave a contribution to the conception of the study, drafting and revising the

manuscript.

Declaration of Competing Interest

None.

Acknowledgments

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2021.106613.

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