Decline in independence after three years and its association with dietary patterns and frailty factors in community-dwelling older people: an analysis by sex and age stage

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Abstract

Background

Support based on sex and age is required to implement longevity strategies. This study clarified the association between declining independence after three years and the dietary patterns and frailty factors of community-dwelling independent older people. We analyzed sex and age stages for people between 65 and 75 years (earlier-stage) and people aged 75 years or above (latter-stage), respectively.

Methods

In a longitudinal study of 25 Japanese prefectures from 2013 to 2016, 3,693 respondents completed baseline and follow-up questionnaires. We analyzed 2,250 participants (1,294 men), after excluding individuals younger than 65 years (n = 510), deceased (n = 35), with missing data (n = 866), or disabled (n = 32). Independence was evaluated based on Instrumental Activities of Daily Living (IADL) scores (maximum = 12). Disability was defined as scoring lower than 9. Dietary patterns were derived from a principal component analysis of 7 food groups. Frailty factors showing a significant relationship with baseline IADL scores were selected. Multivariate logistic regression analysis revealed an association between baseline factors and declining independence after three years.

Results

The average IADL score three years from baseline was 11.5 ± 1.1. There were two IADL score groups: “high independence” (69.6%) and “low independence” (30.4%). Three baseline dietary patterns were identified: “dietary diversity,” “high meat frequency,” “low fruit, vegetable, and dairy product frequency.” The multivariate-adjusted model in the earlier-stage revealed that BMI ≥ 30 (odds ratio (OR) = 0.97, 95% confidence interval (CI): 0.12-7.61) showed no significant difference from 18.5 < BMI (OR = 1). In the latter stage, subjective health and exercising three or more times a week with enjoyment were associated with a lower odds ratio. High meat frequency was related to high OR in all groups, especially latter-stage older women (OR = 1.59, 95% CI: 1.17-2.15).

Conclusions

Effective integrated support for maintaining independence may be associated with weight management for earlier-stage men, the mental/psychological factors in subjective health and exercise enjoyment for latter-stage older people, and limited meat consumption, especially for latter-stage older women.

Background

Although the Japanese overall life expectancy is the longest in the world, the difference between healthy life expectancy and overall life expectancy was reported to be 8.84 years for men and 12.35 years for women in 2016 [1]. Older people are generally defined as 65 years or above, and the risk of requiring nursing care increases at the age of 75 years (latter-stage older people). A loss of independence among community-dwelling older people is attributed to frailty and prefrailty [2]. Frailty is a condition in which resilience to stress is reduced as one's restoration ability declines due to aging [3]. Frailty is a multidimensional concept including physical, mental, psychological, and social factors. It is a high-risk condition that causes serious problems, including reduced independence and death [3]. Approximately 10% of community-dwelling older people present with frailty and the proportion increases with aging [3]. Therefore, it is necessary to provide comprehensive support targeting multidimensional issues that vary according to sex and age, to prevent frailty in older adults.

In 2025, the baby boomer generation in Japan will be 75 years or older, and the proportion of latter-stage older people will increase. Researches on extending healthy life expectancy have shifted their focus to frailty, and the approaches of exercise, nutrition, and social participation are being implemented. Moreover, creating a system that can provide integrated living support, medical and health services, and long-term care prevention is an urgent issue [4]. Nonetheless, the methods for effectively integrating support have not yet been established.

The World Health Organization provided guidelines on community-level interventions called "Integrated care for older people (ICOPE)" to address the issue of global population aging [5]. The guidelines were designed to support health care approaches to meet the needs of community-dwelling older adults and promote effective coordination with long-term care systems [5]. Effective health care support is needed to detect the early stages of frailty to prevent a decline in older people's intrinsic capacity, which can be retained naturally.

Nutrition and diet are highly associated with the risk of frailty in older people [6, 7]. In terms of single nutrients, the intake of proteins that maintain muscle strength [8] and n-3 fatty acids [9] related to cognitive functions are related to frailty prevention. Because healthy diets combine multiple foods, many studies have reported that healthy eating patterns are related to the prevention of frailty in older people [7]. A follow-up study of 71,941 women aged 60 years and above in the United States showed that three diet quality indicators (Mediterranean diet, DASH diet, and Healthy diet index 2010) were associated with a reduction in the relative risk of frailty after 20 years [10]. These healthy eating patterns include a high intake of seafood, vegetables, fruits, whole grains, and olive oil, and a low intake of high-fat foods, meat (red or processed meat), and salt.

Frailty is also associated with the total antioxidant capacity derived from dietary sources, such as coffee, vegetables, and fruits [8]. In a study with Japanese participants, a Japanese-type dietary pattern with low consumption of animal protein, such as beef and pork, and high consumption of rice, miso soup, and fish, was found to be related to a healthy life expectancy with independence [11]. However, an analysis of older

females alone showed that a high-protein (total and animal protein) diet is related to the prevention of frailty onset, independent of the intake of total antioxidant capacity [8].

The multifactorial support of nutrition and diet besides addressing other frailty contributors in older people may be effective in preventing frailty. An intervention focused on physical exercise and nutritional status [12] or a combination of physical, nutritional, and cognitive was most effective for older people with pre- and post-frailty [13]. However, few studies on the multifactorial relationship between dietary patterns and frailty in older people have shown the effects of multifactorial interventions, such as physical activity, cognitive function, and community involvement. Understanding the effective targeting of support by sex and age in older people may provide useful evidence.

Therefore, we conducted a nationwide, longitudinal survey of community-dwelling older people in Japan to assess respondents' instrumental activities of daily living (IADL) three years from baseline and evaluated changes in the degree of their independence. This study aimed to comprehensively clarify the association among a decline in independence over three years, dietary patterns, and frailty factors in community-dwelling independent older people, as analyzed by the sex and age stage of two groups: people between 65 and 75 years (earlier-stage older people) and people aged 75 years or above (latter-stage older people).

Methods

Study participants

This longitudinal survey, which was planned and conducted in collaboration with the Foundation of Social Development for Senior Citizens (FSDSC, Tokyo) and Tokyo Metropolitan University, involved 25 prefectures in Japan. In 2013, a baseline survey of 9,508 residents, who had taken part in healthy longevity events carried out by FSDSC, was conducted (response rate: 45.7%) wherein a questionnaire was sent by the FSDSC's staff to the participants personally or by mail. A follow-up survey using the same questionnaire was conducted three years later and involved 3,990 respondents from the baseline survey who consented to cooperate in the second and subsequent surveys (response rate: 92.6%). A previous paper describes the details of this survey [14].

From the 3,693 valid respondents in both surveys, we excluded surveys of those younger than 65 years (n = 510), deceased (n = 35), or with missing data (n = 866). Their independence was evaluated using the instrumental activities of daily living score (IADL score) [15], which ranged between 1 and 12 points. Disability was operationally defined as participants with an IADL score lower than 9. After excluding 32 individuals, we analyzed the responses of 2,250 people (men: 1,320, women: 962) who were identified as independent.

Evaluation of independence and classification of study participants

For our outcome indicators, we used the 13-item Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC). It evaluates multiple dimensions of IADL, including intellectual and social ADL, of older people [15]. This index also includes a part of a 25-item "*Kihon Checklist*," which was prepared by the Japanese Ministry of Health, Labour, and Welfare. The *Kihon Checklist* is used to screen people aged 65 years or above who require nursing care prevention and has been reported to be a valid method for assessing frailty [16]. In this study, the TMIG-IC was modified to contain only 12 items. For instance, we converted two questions, "Can you read newspapers" and "Can you read books and magazines" into a single item, i.e., "Do you read newspapers and books." The responses of "Yes" and "No" were scored as 1 and 0, respectively, and were summated to obtain each respondent's IADL score. The higher the IADL score (up to 12 points), the higher an individual's degree of independence. In this study, the IADL scores were operationally defined to evaluate frailty condition.

Since no cutoff point has been reported for this index [15], the average value of the participants' IADL scores three years after baseline was calculated. The group was then divided into two: the above-average scores formed the "high independence" group, and the below-average scores formed the "low independence" group.

Evaluation of dietary intake frequency

Dietary habits were collected using the frequency of consumption of food groups in cooking units per week. Seven food groups (meat dishes, soy products, eggs/egg dishes, bluefish, dairy products, fruits, and vegetable dishes) were examined. Frequent consumption of bluefish, which is rich in n-3 fatty acids, is related to the maintenance of cognitive functions in older people [9].

Scoring was based on an ordinal scale: 5 points for "every day," 4 points for "5–6 days a week," 3 points for "3–4 days a week," 2 points for "1–2 days a week," and 1 point for "never." We examined whether these scores were adequate predictors of the participants' independence three years after baseline. The association was examined using the sum of all scores as the "dietary diversity" score. Low independence three years after baseline was set as the dependent variable. The logistic regression analysis, adjusted by sex and age, showed that the dietary diversity scores were significantly related to the prevention of low independence three years after baseline (odds ratio (OR) = 0.947, 95% confidence interval (CI): 0.926–0.969). Therefore, this study found that a higher score for the frequency of dietary intake signaled that a respondent was more likely to maintain independence three years from baseline.

Analysis of frailty factors

The items related to frailty were selected from the "Questionnaire for the Elderly" [17], provided by the Japanese Ministry of Health, Labour, and Welfare to evaluate the health condition of latter-stage older people. The items related to frailty used in this analysis included: (1) health status, (2) psychological and mental health status, (3) weight change, (4) exercise indices related to falls, (5) smoking, and (6) social participation. (1) For the health condition, hospitalization over the previous year was used. (2) Subjective health and life satisfaction were used to identify psychological and mental health conditions. (3) Body Mass Index (BMI) was calculated, using self-reported height and weight, and classified into four

categories: 18.5 < BMI, 18.5 ≤ BMI < 25, 25 ≤ BMI < 30, and BMI ≥ 30. (4) For exercise frequency, we used the index of “exercise frequency with enjoyment and fulfillment” [14] that we developed for a previous study for the same participants. Besides the high frequency of exercise for older people, doing so with enjoyment and fulfillment is strongly related to maintaining independence three years from baseline [14]. There were two questions; the first asked “how much do you exercise or play sports.” We classified each respondent as “exercises three or more times a week” or “exercises two or less times a week.” Next, we asked the participants about their enjoyment and fulfillment. If they responded that they enjoyed their exercise, we reclassified them as “exercises three times or more per week with enjoyment and fulfillment” (or not) and “exercises twice or less per week with enjoyment and fulfillment” (or not). Finally, four categories were created for the exercise index. (4) We also inquired about fall fractures that had occurred over the previous year. (5) We asked the participants to self-report their cigarette smoking status (current, former, never). (6) The respondents’ social participation was tallied through the frequency of their community and volunteer activity engagement. The above items were used in the analysis as multidimensional factors related to frailty.

Other variables

We also analyzed variables related to demographic and socioeconomic status (SES), including age, sex, household status (living alone), economic satisfaction, and salaried job. We used economic satisfaction as an alternative SES variable for annual income, because subjective economic status for older people is more closely related to psychological health than annual income [18].

Analysis

The baseline characteristics were compared between the high and low independence groups after three years, using the Mann–Whitney U test for the ordinal scaled scores (including dietary intake frequency). Chi-squared tests were used for all the other variables. We performed principal component analysis to identify dietary patterns, using the dietary intake frequency scores for seven types of food groups.

Multivariate logistic regression analysis was used to evaluate the association among low independence three years after baseline, dietary pattern, and frailty factors. A significant single relation with low independence three years after baseline was found, with no correlation coefficient of 0.5 or more between the indices.

All statistical analyses were performed using SPSS Statistics 24.0 (IBM). The statistical significance level was set at $p < 0.05$.

Results

Relationship between baseline-related factors and independence three years later

The study participants were 1,294 men (57.5%) and 956 women (42.5%), a total of 2,250 independent older people. The baseline age composition was 1,545 (68.7%) earlier-stage older people (men: 863, 55.9%; women: 682, 44.1%), and 705 (31.3%) latter-stage older people (men: 431, 61.1%; women: 274, 38.9%). The average age was 72.32 ± 5.22 years (men: 72.56 ± 5.43 years, women: 72.01 ± 4.92 years).

The average IADL score three years after baseline was 11.5 ± 1.1, which was significantly lower than the baseline average score of 11.6 ± 0.74. We classified the participants with above-average scores three years after baseline as having high independence (n = 1,565, 69.6%) and those with below-average scores as having low independence (n = 685, 30.4%; Table 1). The proportion of low independence respondents three years after baseline was 37.5% for men, 20.9% for women, 28.3% for earlier-stage older people, and 35.2% for latter-stage older people. Of the low independence participants, 17.9% had no change three years from baseline, whereas 12.5% of the high independence group changed to low independence. Of the high independence group, 60.9% maintained their status three years later, and 8.7% of the low independence group changed to high independence.

Table 1

Relationship between baselines-related factors and independence three years later

		All subjects (n=2,250)					Earlier-stage (n=1,545)					Latter-stage (n=705)				
	Baseline characteristics	High independence		Low independence			High independence		Low independence			High independence		Low independence		
		n	%	n	%	*p*	n	%	n	%	*p*	n	%	n	%	*p*
Sex		1565	69.6	685	30.4		1108	71.7	437	28.3		457	64.8	248	35.2	
	Men	809	62.5	485	37.5	***	547	63.4	316	36.6	***	262	60.8	169	39.2	**
	Women	756	79.1	200	20.9		561	82.3	121	17.7		195	71.2	79	28.8	
Household status																
	Living alone	213	72.0	83	28.0		134	76.6	41	23.4		79	65.3	42	34.7	
	Living alo	1352	69.2	602	30.8		974	71.1	396	28.9		378	64.7	206	35.3	

n, No															
Economic satisfaction#															
Satisfied	414	71.6	164	28.4		276	76.2	86	23.8	*	138	63.9	78	36.1	
Moderately satisfied	873	69.6	382	30.4		611	70.7	253	29.3		262	67.0	129	33.0	
Not very satisfied	225	67.2	110	32.8		173	68.1	81	31.9		52	64.2	29	35.8	
Not satisfied	53	64.6	29	35.4		48	73.8	17	26.2		5	29.4	12	70.6	
Salaried employee															
Yes	336	72.9	125	27.1	*	258	73.1	95	26.9		78	72.2	30	27.8	*

	No	1229	68.7	560	31.3		850	71.3	342	28.7		379	63.5	218	36.5	
Hospitalization over the past year																
	Yes	160	62.7	95	37.3	**	103	63.6	59	36.4	*	57	61.3	36	38.7	
	No	1405	70.4	590	29.6		1005	72.7	378	27.3		400	65.4	212	34.6	
Subjective health#																
	Excellent	297	76.5	91	23.5	***	217	78.3	60	21.7	**	4	44.4	5	55.6	***
	Somewhat healthy	1185	69.4	523	30.6		826	70.6	344	29.4		14	29.8	33	70.2	
	Somew	67	54.0	57	46.0		53	68.8	24	31.2		359	66.7	179	33.3	

hat unhealthy																
Unhealthy	16	53.3	14	46.7		12	57.1	9	42.9		80	72.1	31	27.9		
Life satisfaction#																
Satisfied	1316	71.0	538	29.0	**	927	73.0	343	27.0	*	389	66.6	195	33.4	*	
Neither nor	209	63.3	121	36.7		151	65.7	79	34.3		58	58.0	42	42.0		
Not satisfied	40	60.6	26	39.4		30	66.7	15	33.3		10	47.6	11	52.4		
BMI categories																
18.5 < BMI	58	59.2	40	40.8		34	64.2	19	35.8		24	53.3	21	46.7		
18.	12	70.	51	29.		87	72.	32	27.		35	65.	18	34.		

5 ≤ BMI < 25.0	27	5	4	5		0	6	8	4		7	7	6	3	
25.0 ≤ BMI < 30.0	262	68.1	123	31.9		195	70.1	83	29.9		67	62.6	40	37.4	
30.0 ≤	18	69.2	8	30.8		9	56.3	7	43.8		9	90.0	1	10.0	
Exercise frequency, enjoyment & fulfillment (E&F)															
≥ 3 times/week, E&F	794	71.5	316	28.5		564	72.6	213	27.4		230	69.1	103	30.9	*
≥ 3 times/w	104	69.8	45	30.2		67	71.3	27	28.7		37	67.3	18	32.7	

	eek															
	≤2 times/week, E&F	406	68.5	187	31.5		287	70.9	118	29.1		119	63.3	69	36.7	
	≤2 times/week	261	65.6	137	34.4		190	70.6	79	29.4		71	55.0	58	45.0	
Fall fractures in the past year																
	Yes	155	58.7	109	41.3	***	99	61.9	61	38.1	**	56	53.8	48	46.2	**
	No	1410	71.0	576	29.0		1009	72.9	376	27.1		401	66.7	200	33.3	
Cigaret																

te smoking status#															
Current	51	58.0	37	42.0	***	40	55.6	32	44.4	***	11	68.8	5	31.2	
Former	493	63.0	289	37.0		340	63.3	197	36.7		153	62.4	92	37.6	
Never	1021	74.0	359	26.0		728	77.8	208	22.2		293	66.0	151	34.0	
Community and volunteer activity engagement															
Yes	877	75.3	288	24.7	***	608	77.7	174	22.3	***	269	70.2	114	29.8	***
Sometimes□No	688	63.4	397	36.6		500	65.5	263	34.5		188	58.4	134	41.6	
□The ordinal scaled scores were examined by Mann–Whitney U test □othets were by chi-square tests. * p<0.05, ** p<0.01, *** p<0.001															

Table 1 shows the relationship between the baseline values and the independence scores three years later, with a comparison between the high and low independence group results. The analysis was performed at each age stage. The main item with which only earlier-stage older people showed a significant relationship was smoking; the percentage of those who had never smoked in the high independence group three years after baseline was the highest at 77.8%, whereas those who smoked and became low independence was 44.4%, the highest among the low independence group. An analysis of the BMI categories by sex revealed that the earlier-stage older men showed a significant relationship between the proportion at $18.5 \leq BMI < 25$ and $25 \leq BMI < 30$ who became high independence three years later, at 64.5% and 62.8%, respectively. Of those who were at $18.5 < BMI$ and $BMI \geq 30$, the percentages of low

independence were 64.3% and 71.4%, respectively, which were the highest among the low independence group (p = 0.034, results not shown).

Having salaried employment was the main item in which only the latter-stage older people showed a significant relationship. The percentage of salaried employees who became high independence three years later was the highest at 72.2%, whereas those who were employed without a salary who became low independence reached 36.5%, the highest among the low independence respondents. The results of the exercise frequency of the latter-stage older people showed that the percentage of those who exercised three times or more per week with enjoyment and fulfillment and were identified as having high independence three years after baseline was the highest at 69.1%; those who exercised two or less times a week without enjoyment and fulfillment and had low independence was 45.0%, the highest among the low independence respondents.

Relationship between dietary intake frequency and independence three years later

Table 2 shows the results of the relationship between baseline dietary intake frequency and independence three years later, with a comparison between the high and low independence groups. Overall, the high independence group was significantly higher in the intake frequency of each food group as compared to the low independence group. However, the percentage of those who ate meat every day and became low independence three years later was high among the low independence group (overall result: 32.7%), and it did not differ significantly from those who ate meat 1–2 days a week (32.7%) or did not eat meat (32.8%).

Table 2

Relationship between dietary intake frequency and independence three years later

	All subjects (n=2,250)					Earlier-stage (n=1,545)					Latter-stage (n=705)				
Baseline characteristics	High independence		Low independence			High independence		Low independence			High independence		Low independence		
	n	%	n	%	*p*	n	%	n	%	*p*	n	%	n	%	*p*
Protein foods															
Meat dishes															
Everyday	72	67.3	35	32.7		49	70.0	21	30.0		23	70.0	14	30.0	
5-6day	151	69.6	66	30.4		101	71.1	41	28.9		50	71.1	25	28.9	

saweek														
3-4daysaweek	606	722.7	227	27.3		436	748.8	147	25.2		170	748.8	80	25.2
1-2daysaweek	693	67.3	336	32.7		495	69.8	214	30.2		198	69.8	122	30.2
Never	43	67.2	21	32.8		27	65.9	14	34.1		16	65.9	7	34.1
Soy products														
Everyday	642	74.1	224	25.9	***	426	77.2	126	22.8	***	216	67.9	98	32.1	*
5-6day	261	73.7	93	26.3		185	75.8	59	24.2		76	64.9	34	35.1

sa wee k															
3-4 days a wee k	43 8	67 .5	21 1	32 .5		32 8	67 .9	15 5	32 .1		11 0	14 .3	56	85 .7	
1-2 days a wee k	21 8	59 .7	14 7	40 .3		16 8	64 .9	91	35 .1		50	73 .8	56	26 .2	
Nev er	6	37 .5	10	62 .5		1	14 .3	6	85 .7		5	75 .1	4	24 .9	
Egg s/e gg dish es															
Ev ery day	34 2	70 .5	14 3	29 .5	*	21 1	73 .8	75	26 .2	*	13 1	68 .9	68	31 .1	
5-6 da	22 6	73 .1	83	26 .9		16 6	75 .1	55	24 .9		60	61 .3	28	38 .7	

ysaweek															
3-4daysaweek	553	70.4	233	29.6		398	72.2	153	27.8		155	75.2	80	24.8	
1-2daysaweek	417	66.7	208	33.3		314	68.9	142	31.1		103	62.8	66	37.2	
Never	27	60.0	18	40.0		19	61.3	12	38.7		8	69.2	6	30.8	
Blue fish															
Everyday	80	80.0	20	20.0	***	54	84.4	10	15.6	***	26	73.6	10	26.4	**
5-6days	192	73.8	68	26.2		120	73.6	43	26.4		72	75.1	25	24.9	

a week															
3-4 days a week	605	72.5	230	27.5		428	75.1	142	24.9		177	67.3	88	32.7	
1-2 days a week	647	65.4	342	34.6		477	67.3	232	32.7		170	74.4	110	25.6	
Never	41	62.1	25	37.9		29	74.4	10	25.6		12	77.2	15	22.8	
Other foods															
Vegetable dishes															
Everyday	1,138	72.6	429	27.4	***	791	75.2	261	24.8	***	347	74.9	168	25.1	***

5-6 days a week	253	64.1	142	35.9		182	62.8	108	37.2		71	74.1	34	25.9	
3-4 days a week	140	61.4	88	38.6		110	69.2	49	30.8		30	65.6	39	34.4	
1-2 days a week	34	57.6	25	42.4		25	56.8	19	43.2		9	62.7	6	37.3	
Never	0	0.0	1	100.0		0	#DIV/0!	0	#DIV/0!		0	66.7	1	33.3	
Fruits															
Everyday	932	72.2	359	27.8	***	637	74.9	214	25.1	***	295	75.8	145	24.2	

5-6 days a week	243	71.1	99	28.9		180	74.1	63	25.9		63	73.2	36	26.8
3-4 days a week	247	64.7	135	35.3		177	65.6	93	34.4		70	63.5	42	36.5
1-2 days a week	133	60.7	86	39.3		106	62.7	63	37.3		27	56.9	23	43.1
Never	10	62.5	6	37.5		8	66.7	4	33.3		2	56.9	2	43.1
Dairy products														
Everyd	950	69.9	409	30.1		653	73.2	239	26.8	*	297	75.8	170	24.2

ay												
5-6 days a week	199	75.1	66	24.9	141	75.8	45	24.2	58	73.2	21	26.8
3-4 days a week	207	73.1	76	26.9	156	73.2	57	26.8	51	63.5	19	36.5
1-2 days a week	169	62.6	101	37.4	129	63.5	74	36.5	40	56.9	27	43.1
Never	40	54.8	33	45.2	29	56.9	22	43.1	11	56.9	11	43.1

The ordinal scaled scores were examined by Mann–Whitney U test . * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Dietary patterns

Principal component analysis identified three components that explained 59.4% of the total variance (Table 3). The first component was characterized by a dietary variety that showed that all food groups had strong relations with a high frequency of eating throughout the week. It was described as “dietary diversity.” The second pattern was a negative relationship for vegetable, fruit, and dairy products, which was called “low fruit, vegetable, and dairy product frequency.” The third pattern was a negative

relationship with soy products and bluefish, and a strong positive relationship with a high frequency of meat dishes during the week (principal component loading: 0.660); it was called “high meat frequency.”

Table3 Principal component analysis for dietary patterns

(n=2,250)

	Component		
	[a.] 1	[b.] 2	[c.] 3
Vegetable dishes	**0.645**	**-0.317**	-0.132
Fluits	**0.643**	**-0.434**	0.138
Soy products	**0.621**	0.120	-0.432
Dairy products	**0.548**	**-0.414**	0.239
Eggs/egg dishes	**0.519**	0.430	0.102
Bluefish	**0.466**	0.472	-0.398
Meat dishes	**0.404**	0.475	**0.660**
Total variance (%)	30.9	46.7	59.4

Dietary patterns were described as follows;

[a.] Component 1: “Dietary diversity”

[b.] Component 2: “Low fruit, vegetable, and dairy product frequency”

[c.] Component 3: “High meat frequency”

Comprehensive analysis of low independence three years from baseline

Table 4 shows the multivariate-adjusted logistic regression models analyzed by sex and age group, using indices showing significant relationships with independence three years later (Tables 1 and 2). The indices that showed significantly lower odds ratio (OR) against low independence three years later for both sexes and age stages were dietary diversity (earlier-stage older people: OR = 0.82, 95% CI: 0.73-0.93; latter-stage older people: OR = 0.81, 95% CI: 0.68-0.97), no fall fractures in the previous year (OR = 0.54, 95% CI: 0.37-0.78; OR = 0.60, 95% CI: 0.38-0.95), and community and volunteer activity engagement (OR = 0.54, 95% CI: 0.42-0.68; OR = 0.68, 95% CI: 0.49-0.96). Conversely, high meat frequency had a significantly high OR against low independence three years later for both sexes and age stages (OR = 1.21, 95%CI: 1.07-1.36; OR = 1.20, 95%CI: 1.02-1.41). Subjective health was significantly associated only with the latter-stage older people (OR = 0.64, 95% CI: 0.45-0.91) as was exercising three or more times per week with enjoyment and fulfillment (OR = 0.56, 95% CI: 0.36-0.89).

Table 4

Multivatiate-adjusted logistic regression annalysis for low independence three years after baseline

Baseline characteristics	Earlier-stage		Latter-stage		Men				Women			
					Earlier-stage		Latter-stage		Earlier-stage		Latter-stage	
	(n=1,545)		(n=705)		(n=864)		(n=431)		(n=682)		(n=274)	
	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Dietary pattern												
Dietary	0.82 (0.73 – 0.93)	**	0.81 (0.68 – 0.97)	*	0.84 (0.73 – 0.98)	*	0.77 (0.63 – 0.96)	*	0.74 (0.58 – 0.94)	*	0.91 (0.63 – 1.31)	

diversity						
Low fruit, vegetable, and dairy product frequency	0.98 (0.87, 1.11)	0.96 (0.82, 1.14)	0.97 (0.84, 1.13)	0.98 (0.80, 1.20)	1.01 (0.82, 1.25)	0.96 (0.70, 1.30)
High	1.21 (1.07, 1.36)*	1.20 (1.02, 1.41)*	1.18 (1.01, 1.38)*	1.08 (0.88, 1.31)	1.25 (1.02, 1.53)*	1.59 (1.17, 1.15)**

meat frequency						
Economic satisfaction	1.03 (0.87–1.21)	1.02 (0.79–1.30)	1.05 0.84–1.30)	1.05 (0.77–1.43)	1.02 (0.78–1.33)	0.98 (0.64–1.50)
Salaried employee (ref: No)	0.86 (0.64–1.14)	0.73 (0.44–1.19)	0.88 (0.62–1.24)	0.68 (0.37–1.25)	0.78 (0.45–1.34)	0.92 (0.39–2.16)

Nohospitalizationovertheprevious year (ref: Yes)	0.85 (0.59 – 1.22)	1.00 (0.62 – 1.61)	0.86 (0.56 – 1.32)	0.87 (0.47 – 1.58)	0.93 (0.44 – 1.94)	1.40 (0.60 – 3.25)
Subjective health	0.84 (0.66 – 1.07)	0.64 (0.45 – 0.91)*	0.74 (0.54 – 1.02)	0.68 (0.44 – 1.07)	0.92 (0.61 – 1.38)	0.54 (0.30 – 0.99)*
L	0 (1	0 (1	1 (1	0 (1	0 (1	0 (1

ifesatisfaction	.93	0.72	.22)	.85	0.59	.22)	.07	0.76	.50)	.83	0.52	.33)	.74	0.48	.14)	.93	0.50	.71)
BMI categories ref 18.5 < BMI																					
18.5 ≤ BMI < 25.0	0.47	(0.26	0.88)	0.64	(0.33	1.24)	0.25	(0.08	0.82)	0.57	(0.22	1.51)	0.60	(0.27	1.30)	0.73	(0.28	1.90)

25.0≤BMI<30.0	0.49 (0.25–0.94)*	0.73 (0.34–1.56)	0.28 (0.08–0.93)*	0.69 (0.24–1.96)	0.49 (0.19–1.25)	0.69 (0.19–2.43)
30.0≤	0.82 (0.25–2.77)	0.09 (0.01–0.83)*	0.97 (0.12–7.61)	–	0.49 (0.08–3.24)	0.19 (0.02–2.36)
Exercise frequency, enjoyment & fulfillment (E&F) (ref: ≤2 times / week)						
≥3 times / week, E&F	0.95 (0.67–1.33)	0.56 (0.36–0.89)*	0.87 (0.56–1.35)	0.59 (0.33–1.05)	1.14 (0.66–1.97)	0.49 (0.22–1.09)
≥3 times / we	1.11 (0.64–1.93)	0.61 (0.30–1.25)	1.27 (0.64–2.54)	0.74 (0.29–1.85)	0.94 (0.35–2.57)	0.43 (0.13–1.43)

ek					
≤2 times /week, E&F	0.90 (0.63 1.30)	0.66 (0.40 1.08)	0.90 (0.56 1.45)	0.62 (0.32 1.20)	0.90 (0.50 1.65)	0.73 (0.33 1.60)
No fall fractures in the past year ref Yes	0.54 (0.37 0.78)**	0.60 (0.38 0.95)*	0.66 (0.39 1.10)	0.83 (0.45 1.54)	0.41 (0.24 0.70)**	0.43 (0.21 0.88)*

Nocigarettesmokingstatus	0.83	(0.66 | 1.04)	1.32	(0.92 | 1.90)	0.85	(0.66 | 1.10)	1.31	(0.90 | 1.90)	0.69	(0.40 | 1.20)	1.43	(0.28 | 7.22)
Communityandvolunteeractivityengage	0.54	(0.42 | 0.68)**	0.68	(0.49 | 0.96)*	0.44	(0.33 | 0.60)**	0.75	(0.49 | 1.13)	0.79	(0.52 | 1.20)	0.58	(0.32 | 1.07)

ment ref Sometimes No																
Sex ref Men	0.39	(0.28	0.53)	**	0.50	(0.33	0.76)	**								
Age +1 years old	0.98	(0.94 | 1.02)		1.03	(0.98 | 1.09)		0.97	(0.92 | 1.02)		1.02	(0.96 | 1.08)		0.99	(0.92 | 1.07)		1.06	(0.97 | 1.15)	

Logistic regression analysis was conducted. OR odds ratio, CI confidence interval, ref refference, * $p<0.05$, ** $p<0.01$, *** $p<0.001$
Model 2,363

The analysis by sex and age group revealed that earlier-stage older men showed a significantly high OR for 18.5 ≤ BMI < 25 (OR = 0.25, 95% CI: 0.08-0.82) and 25 ≤ BMI < 30 (OR = 0.28, 95% CI: 0.08-0.93). The

OR for having a BMI < 18.5 or a BMI ≥ 30 did not differ significantly from one another (OR 0.97, 95% CI 0.12-7.61). The OR for community and volunteer activity engagement (OR = 0.44, 95% CI: 0.33-0.60) was found to be significantly low.

The results also indicated that latter-stage older women showed a significantly low OR for no fall fractures in the previous year (OR = 0.43, 95% CI: 0.21-0.88) and subjective health (OR = 0.54, 95% CI: 0.30-0.99). The OR for high meat frequency in the latter-stage older women was significantly higher in all results, regardless of sex or age (OR = 1.59, 95% CI: 1.17-2.15).

Discussion

The present study aimed to clarify how multidimensional factors, especially dietary patterns, affect a decline in independence after three years. This study was a nationwide longitudinal survey of community-dwelling independent older people in Japan. Our results revealed commonalities and distinctions by sex and age stage. Dietary patterns were categorized as dietary diversity, high meat frequency, and low fruit, vegetable, and dairy product frequency.

Evaluation of low independence after three years

In this study, low independence was defined as a below-average IADL score of the survey respondents. The mean IADL score after three years was significantly lower than that at baseline. Of the percentage of low independence respondents three years later (30.4%), 12.5% changed from high to low independence. This result was higher than the percentage of those who changed from low to high independence (8.7%). However, the changes in identification from low to high independence suggest that it is possible to maintain or improve independence at this stage. Effective health care support based on the needs of older people is important.

Relationship between dietary patterns and low independence three years later

In our multivariate analysis, dietary diversity appeared to prevent low independence after three years. Consuming various types of foods leads to a varied nutritional intake, which is related to maintaining independence in old age. Additionally, there are many opportunities for a well-balanced combination of dishes [19], which is associated with frailty prevention [7].

In a study in the United States [10], older people with a high score for three healthy dietary patterns had a higher ratio of monounsaturated fatty acids, such as olive oil, than saturated fatty acids, such as meat, a high intake of vegetables, moderate alcohol, and a low intake of processed and unprocessed meat and salt. According to a report from Taiwan [20], the dietary pattern related to frailty prevention constituted vegetables and fruits with high antioxidant capacity, teas, fish rich in n-3 fatty acids, and other high-protein foods, such as seafood and dairy products, and whole grains. Common to these reports is a healthy dietary pattern with a low intake of meats and saturated fatty acids.

In this study, high meat frequency had a significantly high OR for low independence after three years in all analyses, except for older men. The results of this study support the findings of previous studies that revealed the relationship between frailty and diet in older people [7, 10, 11, 20].

Diets with a high intake of animal protein, such as meats rich in saturated fatty acids, and a low intake of bluefish, which is rich in n-3 fatty acids, and soy-based foods with vegetable protein, may promote a decline in independence. Meat may play a key role in the relationship between inflammation and low independence in older people. The Dietary Inflammatory Index (DII) [21] is an index created by Shivappa and colleagues that scores 45 types of foods and nutrients based on their inflammatory properties according to a review of 1,943 research papers. The DII scores have been validated with inflammatory markers, such as blood C-reactive protein (CRP), which is an indicator of chronic inflammation [21]. Many studies have reported that older people on a high pro-inflammatory diet with high DII scores are associated with disability or death [22]. Those on a moderately pro-inflammatory diet were associated with frailty and were independent of obesity [23].

The DII score of saturated fatty acids, which are abundant in meat, is 0.373. This is the highest possible score and is evaluated as the highest pro-inflammatory nutrient [21]. Conversely, the n-3 fatty acids contained in bluefish are − 0.436 [21]. Using the National Health and Nutrition Survey Data of 2,572 Japanese adults, a positive association was found between DII scores and CRP, and the participants in the group with a low DII score consumed a diet rich in vegetables, fruits, seafood, and beans, and their intake of meat and cereals was low [24]. The higher the DII score, the higher the likelihood of observing high meat intake in Japanese adults. The results of the present study showed that the frequent intake of meat in older people, especially older women, was related to a decline in independence after three years, independent of multidimensional frailty and adjusted factors. These results may be explained by the pro-inflammatory nature of saturated fatty acids in meat.

In recent years, high protein intake by older people has been recommended as a support for frailty prevention. Meat from mammals, compared to seafood and soy-based foods, has better micronutrients against aging, such as the arachidonic acid of an n-6 fatty acid [9], and zinc, which helps prevent cognitive decline. The recommendation of eating moderate amounts of meat along with other variety of food is necessary for older people and should be included in nutrition education.

Comprehensive analysis of low independence after three years

A single intervention with nutrition for frailty may have little effect. There may be stronger results from an intervention that combines physical activity, nutrition [12], and cognitive function [13]. However, the effects of multiple interventions focusing on dietary patterns have not been fully clarified. For older women, who have a longer life expectancy than men and a large difference between healthy life expectancy or not, it is critical to standardize effective support. To that end, it is important to clarify relevant frailty factors comprehensively by sex and age stage and accumulate evidence to create an effective integrated support program. The current study is among the first to evaluate the multifactorial

association among a decline in independence, dietary patterns, and frailty factors in earlier- and latter-stage older people, individually.

The results of this study showed that an appropriate BMI was associated with the prevention of a decline in independence in earlier-stage older men. Earlier-stage older people were determined between 65 and 75 years old, suggesting the necessity of continuing measures, such as weight management, to prevent chronic lifestyle diseases and aggravation. Additionally, the OR of obesity with a BMI of 30 or more in latter-stage older people in the present study was significantly lower, at 0.09, and the effect on a decline in independence was smaller than the thinness of a BMI of less than 18.5. However, in a study of Japanese participants, obesity in latter-stage older people was significantly higher with an OR for the loss of independence of 1.4 [2]. These results suggest that latter-stage older people, both lean and obese, should be considered in measures to support frailty.

Our results of the latter-stage older people suggest that subjective health and exercise frequency with enjoyment and fulfillment may be priority support items for preventing a decline in independence after three years. Furthermore, social participation, such as community and volunteer activity engagement, could contribute to its prevention for both earlier- and latter-stage older people. The vulnerability of mental and psychological factors in older people is one of the multifaceted problems associated with frailty. Particularly, this study suggests that consideration of mental and psychological factors must be included in the support offered to latter-stage older people.

A cross-sectional study of community-dwelling older people in Hong Kong reported that a Mediterranean diet, one's living space, and social participation opportunities were associated with risk reduction for frailty [25]. This result suggests that dietary lifestyle in older people may be determined by their lifestyle. A decrease in food intake in independent older people was significantly related to a decrease in the outing frequency of less than once a week with an OR of 2.0 [26]. Therefore, it is necessary to provide environmental support to facilitate older people's flexibility and ability to walk around their residence. Likewise, older people may go out more.

Hoshi [27] clarified the causal structure of multiple factors associated with extending a healthy life expectancy. The results of the analysis model show that there is an indirect relationship between socioeconomic status (SES) and healthy life expectancy, mediated by the effects of environmental status (green living environment), and mental, physical, and social health. In this study, multivariate analysis did not show any significant correlation with SES-related satisfaction. However, the results on the subjective economic status of the earlier-stage older people revealed that the percentage was highest for "satisfied" (76.2%) in the high independence group, whereas "not very satisfied" (31.9%) was the highest in the low independence group.

Therefore, effective support for older people living in communities needs to account for SES. Creating a multifactorial program for an integrated support, designed by sex and age stage, might be more effective. Moreover, the use of resources other than specialists has been reported [28]. For example, utilizing earlier-

stage older people as leaders in volunteer activities in a frailty prevention program for the latter group may present a model of support in the future.

We should consider several limitations of this study. First, we evaluated the respondents' independence using the validated TMIG-IC, which asked for subjective information on the participants' ability to engage in IADL. Converting the analysis outcomes into a numerical index, such as for healthy life expectancy, which is calculated by a period of not needing nursing or support [29], and identifying various factors related to a reduction in healthy life expectancy will strengthen the evidence found in this study. More studies are needed to address these issues.

Next, the results were based on the frequency of food group consumption. Although the BMI related to total intake was added to the analysis in the multivariate-adjusted model, it was not the result calculated based on quantitative intake. Future studies should further examine the intake of foods and nutrients and perform quantitative verification.

Conclusions

Our results suggest that the priority factors of effective and integrated support for maintaining independence after three years are associated with the prevention of diseases and aggravation. It mainly includes weight management for earlier-stage older men, mental and psychological factors related to subjective health and enjoyment and fulfillment, especially for latter-stage older people, and low consumption of meat for latter-stage older women.

Abbreviations

BMI:Body Mass Index, CI:Confidence interval, DASH:Dietary Approaches to Stop Hypertension, IADL:Instrumental activities of daily living, ICOPE:Integrated care for older people, n-3:Omega-3, n-6:Omega-6, OR:odds ratio, TMIG-IC:Tokyo Metropolitan Institute of Gerontology Index of Competence, FSDSC:Foundation of Social Development for Senior Citizens

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Review Committee for research on humans at Sagami Women's University (No. 1793, October 27, 2017). The questionnaire was anonymized (ID numbering) to protect personal information. All study participants provided written informed consent.

Consent for publication

Not applicable.

Availability of data and materials

The data that support the findings of this study are available from the Tokyo Metropolitan University. However, restrictions apply on the availability of these data, which were used under the license for the current study and are not publicly available. Nevertheless, data are available from the authors upon reasonable request and with permission of the Tokyo Metropolitan University.

Competing interests

The authors declare no competing interests.

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Authors’ contributions

TH designed and conducted the survey and prepared raw data. TH, SuK, and SaK maintained, analyzed, and interpreted the data. SaK was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

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