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Changes in health behaviors and the trajectory of body mass index among older Japanese: A 19-year longitudinal study

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Aim: Although the modification of lifestyle factors might facilitate weight control, the effects of health behaviors on the trajectory of bodyweight among older adults have been understudied. We examined the effect of changes in smoking, alcohol use and physical activity on the long-term trajectory of body mass index (BMI) among older Japanese adults.

Methods: Data came from a national sample of 4869 Japanese adults aged 60 years and older at baseline, with up to seven repeated observations over a period of 19 years (1987–2006). Hierarchical linear modeling was used to analyze the intrapersonal and interpersonal differences in BMI trajectory.

Results: The average BMI among older Japanese adults was 22.3 at baseline, and decreased with an accelerating rate over time. Smoking was significantly associated with lower BMI over time, whereas smoking cessation was associated with higher BMI. Drinking and physical activity were not associated with BMI. We found significant interactions between age and smoking status, and between sex and physical activity, on BMI trajectory: the association between smoking and lower BMI was stronger in younger participants compared with older participants. The association between physical activity and higher BMI was more pronounced among men compared with women.

Conclusion: The present findings yield important new information regarding the complex dynamics underlying the linkage between lifestyles factors and BMI trajectory among older Japanese, and suggest that there might be cross-cultural differences in these linkages. **Geriatr Gerontol Int 2017; 17: 2008–2016.**

Keywords: body mass index, health behavior, hierarchical linear modeling, Japan, trajectory.

Introduction

Weight change has been shown to predict mortality risk. Weight loss, in particular unintentional weight loss, has been associated with an increased risk of all-cause mortality, while findings on the relationship between weight gain and mortality have been mixed in older populations.[1–5] Most studies have defined weight change on the basis of body mass index (BMI) measured at two points in time over a relatively short interval. However, because bodyweight can fluctuate substantially over the adult life course, analyzing weight changes across multiple points in time (i.e. the trajectory of BMI) might be important in understanding weight control and management of weight-related conditions in late life.[6–8]

The modification of lifestyle factors, such as smoking,[9–11] alcohol use[12,13] and physical activity[14] could facilitate weight control in middle- and older age. However, to our knowledge, there has been only one study exploring the relationship between changes in lifestyle factors and the trajectory of BMI in this age group. A 14-year longitudinal study of American adults aged 51–61 years at the baseline, showed distinct patterns of stability and changes (initiation and cessation) in smoking, alcohol use and physical activity, and a complex association with the trajectory of BMI.[15] In particular, smoking and physical activity were associated with a descending BMI trajectory, whereas cessation of smoking and physical activity were associated with an ascending BMI trajectory.

However, populations in Western countries differ significantly from those in non-Western countries, both in terms of bodyweight and lifestyle factors.[16,17] Furthermore, education and household income appear to be associated with BMI among older Japanese adults[18] in

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different ways from those among older Americans.[6] In addition, the proportions of non-smokers and people who engage in high-intensity activity among Japanese adults are lower than those among American adults.[19,20] Because most research on BMI trajectories among older people is based on data derived from Western societies, particularly the USA, it is important to explore if the relationship between lifestyle factors and BMI trajectories differ among older Japanese. This could inform the design of health policies and interventions aimed at promoting and maintaining bodyweight in late life, particularly in Asian populations.

Furthermore, in light of the age and sex differences in the prevalence of overweight/obesity, smoking, alcohol consumption and daily physical activity among older Japanese adults, it is also important to explore whether the association between lifestyle factors and BMI trajectory vary according to age and sex.[16] This knowledge could contribute to the design of effective clinical and public health interventions aimed at maintaining healthy weight among older adults.

The purpose of the present study was to examine the association between health behaviors (smoking, alcohol use and physical activity) and BMI within the context of the long-term trajectory of bodyweight among older Japanese adults. In addition, we analyzed age and sex variations in the associations between health behaviors and BMI trajectory. Because health behaviors can vary over time within individuals, we specified health behaviors as time-varying covariates to more accurately describe the actual change in behavioral patterns.[21,22]

Methods

Sample and procedures

Data came from the National Survey of the Japanese Elderly, a seven-wave (1987, 1990, 1993, 1996, 1999, 2002 and 2006) longitudinal panel of 4869 Japanese adults, aged 60 years of age and older, with 16 669 observations over 19 years (1987–2006). This sampling procedure has been previously described in detail.[18,22] This survey began with 2200 respondents aged 60 years and over in 1987 (wave 1). The sample was subsequently supplemented in 1990 (wave 2; n = 580) and 1996 (wave 4; n = 1210). An additional sample of those aged 70 years and older was added in 1999 (wave 5; n = 2,000). The number of study participants at each wave and the number of observations of participant individuals by entry wave are shown in Supporting information 1 and 2. Trained investigators visited the respondents' homes, and face-to-face interviews using a structured questionnaire were used to collect the data. The study was approved by the institutional review board of the Tokyo Metropolitan Institute of Gerontology.

Measures

BMI

Respondents' self-reported height and weight were recorded at each wave. The dependent variable BMI was calculated according to the formula: BMI = weight (kg)/ height (m).[2]

Health behaviors status and changes

Current smoking, alcohol use and physical activity were recorded at every wave (time-varying variables). With regard to smoking and alcohol use, participants were classified into "0 = non-users" or "1 = users". For physical activity, we used two items: regular exercise and walking over 1 km in daily life ("0 = rarely/never" or "1 = often/ sometimes"). Generally, physical activity includes exercise that is planned, structured, repetitive and purposeful in the sense that the improvement or maintenance of one or more components of physical fitness is the objective, and other activities that involve bodily movement and are carried out as part of playing, working, active transportation, house chores and recreational activities.[23] Therefore, we set these two items, and classified participants into three categories at each time-point: "0 = doing neither activities (non-active)," "1 = doing either (moderately active)" or "2 = doing both (active)."

Changes in each behavior between two adjacent waves were captured by a difference score (i.e. difference between current [t_i] and previous observation [$t_i - 1$]) calculated for each wave. For smoking and alcohol use, three categories were created (i.e., −1 = cessation, 0 = no change, 1 = initiation). For physical activity, five categories were possible, ranging from −2 to 2; however, for consistency with analyses and interpretation on smoking and alcohol use, we reclassified them into three categories: −1 = cessation (including all levels of reduction]), 0 = no change and 1 = initiation (including all levels of increase). This approach is consistent with previous research, which used the same analytic framework for older Americans.[15]

Covariates

Age, sex and education were used as time-constant variables recorded at baseline. Additional time-varying covariates were included: marital status, working status, annual household income and three measures assessing health status. Household income was assessed by using five categories: "1=less than 1.2 million yen per year," "2 = 1.2–3 million yen per year," "3 = 3–5 million yen per year," "4 = 5–10 million yen per year" and "5 = >10 million yen per year." Three measures of health status were included: (i) chronic conditions, measured as a count of 16 chronic diseases (e.g. cancer, high blood pressure, heart conditions, diabetes, stroke); (ii) self-rated health, measured by a three-item composite with scores ranging from 3 to 15 (Cronbach's alpha = 0.85), and a high score indicates poorer health; and (iii) functional status, measured as a sum of difficulties with six activities of daily living and five instrumental activities of daily living. With regard to functional status, all items were scored by either a 4- or 5-point scale, and with appropriate adjustment, scores for this composite ranged from 11.5 to 55 (Cronbach's alpha = 0.92); a higher score reflects greater functional disability.

Statistical analysis

Hierarchical linear models were used to chart the trajectory of BMI from 1987 to 2006. Hierarchical linear models are well suited for studies of individual changes over time, using repeated measures of a construct to estimate a growth trajectory defined by intercept (i.e. level during the observation) and slope (i.e. rate of change, such as rate of linear change and rate of acceleration). The analytical strategy used a series of time-based models sequentially adjusted to control for interpersonal age-at-baseline and sociodemographic differences. The year when a respondent was first interviewed was used as the baseline for each individual. Time (i.e. the distance of assessment from the baseline) was centered on its grand mean (5.43 years) to minimize the possibility of multicollinearity when estimating non-linear time functions. All models were fitted by using HLM 7 (Scientific Software International, Inc., Skokie, IL).

BMI at a given time (level 1 equations) was specified as a function of time (i.e. distance from baseline year) and time-varying covariates (e.g. smoking, alcohol use, physical activity, marital status, working status, household income and health status). To ensure a clear time sequencing between dependent and independent variables, each time-varying covariate was represented by two distinct measures: a lagged measure (i.e. observation from the previous wave [$t_i - 1$]) and a change term (i.e. difference between current [t_i] and previous observation [$t_i - 1$]). Furthermore, two interaction terms were created for each health behavior and added in the level 1 equations to assess whether the strength of the association between the lagged status or the change score and BMI trajectory varied by age and sex (e.g. [lagged smoking × age] and [δ smoking × age]). Interpersonal variations were evaluated by including time-constant covariates, such as age-at-baseline, sex, education and baseline BMI level in the level 2 equations.

To adjust for possible selection bias, we included mortality and attrition as a result of non-response in the level 2 equation. To minimize missing data as a result of item non-response, multiple imputation was undertaken. In particular, three complete datasets were imputed with the NORM software.[24] The modeling strategy involved the following five steps: model 1 included health behaviors (both lagged and change terms) and time-constant covariates; model 2 added marital status, working status, household income and health status; model 3 was additionally

Table 1 Baseline characteristics of the participants

	Total	Male	Female
Female	55.3	–	–
Age (years)	69.85 (7.20)	69.41 (7.10)	70.21 (7.27)
Education (years)	9.16 (2.76)	9.77 (2.95)	8.66 (2.49)
Married	67.1	88.3	49.9
Current working	31.7	44.5	21.2
Household income (range 1–5)	2.87 (1.10)	3.07 (1.07)	2.71 (1.10)
Total condition (range 0–16)	1.23 (1.36)	1.11 (1.28)	1.33 (1.42)
Self-rated health (range 3–15)	7.69 (2.81)	7.41 (2.81)	7.92 (2.80)
Functional status (range 11.5–55)	12.56 (3.81)	12.35 (3.53)	12.72 (4.00)
Dead	36.7	44.9	30.1
Attrition	21.0	15.6	25.4
Body mass index	22.26 (3.24)	22.06 (2.95)	22.42 (3.44)
Underweight (<18.5)	10.7	10.3	11.1
Normal (18.5–25.0)	71.7	75.5	68.7
Overweight (>25.0)	17.6	14.3	20.2
Smoking	24.5	45.1	7.9
Alcohol use	40.3	63.8	21.3
Physical activity			
Active	38.6	41.6	36.1
Moderate	33.6	31.7	35.2
Non-active	27.8	26.7	28.8

Values represent % or mean (standard deviation); $n = 4869$.

Table 2 Variation in body mass index and health behaviors by wave (1987–2006)

	Wave 1 (1987)	Wave 2 (1990)	Wave 3 (1993)	Wave 4 (1996)	Wave 5 (1999)	Wave 6 (2002)	Wave 7 (2006)	Total
Total participants at each wave	2200	2037	1841	2429	3424	2718	2020	16 669
Body mass index	21.94 (3.25)	21.98 (3.14)	22.01 (3.24)	22.29 (3.21)	22.30 (3.31)	22.23 (3.31)	22.22 (3.37)	22.16 (3.27)
Smoking	0.28 (0.45)	0.27 (0.44)	0.24 (0.43)	0.22 (0.42)	0.18 (0.39)	0.15 (0.35)	0.10 (0.30)	0.20 (0.40)
1 = yes	28.2	27.0	24.0	22.4	18.2	14.6	10.2	20.3
0 = no	71.8	73.0	76.0	77.6	81.8	85.4	89.8	79.7
Change in smoking (delta)		−0.01 (0.26)	−0.02 (0.25)	−0.02 (0.22)	−0.03 (0.22)	−0.03 (0.22)	−0.05 (0.26)	−0.03 (0.24)
1 = initiation		2.7	1.9	1.4	0.9	0.9	1.0	1.4
0 = no change		93.4	93.8	95.1	94.9	94.8	92.9	94.2
−1 = cessation		3.9	4.3	3.6	4.2	4.2	6.1	4.4
Alcohol use	0.38 (0.48)	0.39 (0.49)	0.37 (0.48)	0.40 (0.49)	0.36 (0.48)	0.35 (0.48)	0.32 (0.47)	0.37 (0.48)
1 = yes	37.8	38.7	37.4	40.5	36.2	34.7	32.3	36.8
0 = no	62.2	61.3	62.6	59.5	63.8	65.3	67.7	63.2
Change in alcohol use (delta)		−0.02 (0.40)	−0.01 (0.38)	−0.04 (0.37)	−0.04 (0.37)	−0.04 (0.37)	−0.05 (0.38)	−0.03 (0.38)
1 = initiation		7.0	6.9	4.7	4.9	5.1	4.7	5.5
0 = no change		84.3	85.3	86.2	85.9	86.3	85.6	85.6
−1 = cessation		8.7	7.8	9.1	9.3	8.6	9.7	8.9
Physical activity	1.09 (0.81)	1.11 (0.79)	1.22 (0.79)	1.14 (0.79)	1.12 (0.82)	1.13 (0.82)	0.11 (0.82)	1.13 (0.81)
2 = active	37.5	37.2	44.2	39.3	40.6	40.6	39.3	39.8
1 = moderate	34.2	36.6	33.5	35.4	30.6	31.6	32.1	33.2
0 = non-active	28.3	26.2	22.3	25.3	28.7	27.8	28.6	27.0
Change in physical activity (delta)		−0.02 (0.73)	0.07 (0.70)	−0.11 (0.71)	−0.03 (0.72)	−0.04 (0.69)	−0.04 (0.70)	−0.03 (0.71)
1 = initiation		25.5	28.0	20.2	24.1	22.3	22.4	23.7
0 = no change		47.3	51.0	48.7	48.6	51.7	51.1	49.9
−1 = cessation		27.2	21.1	31.1	27.3	25.9	26.5	26.4

Values represent number, mean (standard deviation) or %.

adjusted for baseline BMI; and models 4 and 5 added age and sex interaction terms, to evaluate age and sex differences in the association between health behaviors and BMI trajectories. Supporting information 3 provides more detailed descriptions of the analytical strategy.

Results

Table 1 presents descriptive statistics for the study participants at the baseline. Women accounted for 55.3% of the sample, and the average age of the respondents was 69.85. The proportions of people who died during the study, and who dropped out for reasons other than mortality and did not return in subsequent waves were 36.7% and 21.0%, respectively. The average BMI was 22.26. The proportions of respondents who smoked and drank alcohol were 24.5% and 40.3%, respectively. In addition, 38.6%, 33.6% and 27.9% of the respondents were active, moderate and non-active in physical activities. Table 2 shows time-varying characteristics by wave, including BMI, smoking, alcohol use and physical activity. Average BMI during the 19-year observation was 22.16.

Table 3 shows the results of the multilevel linear regression model. To show the trajectory of BMI between 1987 and 2006, we evaluated linear, quadratic and cubic models, and chose the most appropriate one on the basis of the statistical significance of higher-order fixed effects estimates. As the cubic coefficient was not statistically significant, the change in BMI was best described by a quadratic function. The unconditional model showed that BMI decreased with a quadratic curve (from 22.3 to 21.2 over the 19 years of observation).

In model 1, smoking was significantly associated with lower BMI over time (b = −0.722). Furthermore, its cessation was significantly associated higher BMI (b = −0.431). Although drinking and physical activity were not associated with BMI in model 1, initiations/increases of these health behaviors were associated with higher BMI over time (b = 0.154 for alcohol use and 0.067 for physical activity). When adjusting for both lagged status and change terms of covariates in model 2, the effects of initiation/increase of alcohol use and physical activity became non-significant. These estimates remained non-significant in model 3 (adjusting for baseline BMI). However, the effects of smoking and its change on BMI remained significant in models 2 and 3 (e.g. b = −0.358 and −0.281 in model 3).

Models 4 and 5 examined age and sex differences in the association between health behaviors and BMI. Model 4 showed a significant interaction between age and lagged smoking status on BMI (b = 0.040), indicating that smokers had lower BMI than non-smokers in younger cohorts, but this effect became smaller in older cohorts. In model 5, significant interactions between sex and physical activity, and between sex and the initiation of physical activity, on BMI were observed (b = −0.129 and −0.144). This showed that the effects of physical activity and initiation/increase of physical activity on higher BMI were greater among men compared with females. In order to confirm these interactions, we carried out sex-stratified analysis, and found significant associations between physical activity (of both lagged and change terms) and higher BMI in the male subsample, but not in the female subsample (see Supporting information 4).

Discussion

The present study examined the association between changes in smoking, alcohol use, and physical activity and the trajectory of BMI among older Japanese adults over the course of a 19-year period. To our knowledge, this is the first study to explore these effects in the older Japanese population. The present findings suggest lifestyle interventions as possible clinical and public health tools aimed at promoting and maintaining healthy bodyweight in older age.

Smoking was associated with lower BMI, whereas its cessation was associated with higher BMI. Nicotine intake is accompanied by a decreased consumption of sweet-tasting high caloric foods.[25] In fact, cross-sectional studies reported the relationship between smoking and lower bodyweight,[9,10] including a study in Japan.[11] It is also suggested that smoking quitters tend to gain weight.[26] In addition, the present results regarding the effect of smoking on BMI trajectory are consistent with previous research focusing on BMI trajectory among Americans aged 51–61 at baseline.[15] However, the effects of smoking (i.e. lagged smoking status and changes in smoking) seemed to be smaller in older Japanese adults than those in older Americans (e.g. compared with non-smokers, 0.36–0.73 BMI units lower for smokers in our samples, but 1.05–1.38 BMI units lower in older Americans[15]). Of course, because the age of the sample, sample size and covariates adjusted in the models were different between these two cohorts, direct comparisons of these values should be made with caution. However, if this difference is valid, it might be due to the difference in the BMI level between two older populations.[16,17] That is, as the average BMI among older Americans is higher than that among older Japanese adults, the effects of smoking on decreases of bodyweight might be greater.

Additionally, a significant interaction between age and lagged smoking status on BMI was observed in model 4. This suggests that smoking was associated with lower BMI than non-smoking in younger cohorts, but this association became smaller in older cohorts. Among Americans, the difference in BMI between smokers and non-smokers was also greater in young cohorts than among middle-aged cohorts.[27] The sample of the present study was limited to older ages, but the trend of age differences in the linkage between smoking and bodyweight seems similar. Previous research has reported that the

Table 3 Effect of health behaviors on the trajectory of body mass index

	Model 1	Model 2	Model 3	Model 4	Model 5
Fixed effect					
Time-varying					
Smoking					
Lagged	−0.722***	−0.730***	−0.358***	−0.266**	−0.359**
Delta	−0.431***	−0.441***	−0.281**	−0.231*	−0.298*
Lagged × baseline age				0.040**	
Delta × baseline age				0.020	
Lagged × female					−0.006
Delta × female					−0.063
Drinking					
Lagged	0.137	0.066	0.038	0.004	0.040
Delta	0.154*	0.108	0.096	0.103	0.097
Lagged × baseline age				−0.016	
Delta × baseline age				0.001	
Lagged × female					0.035
Delta × female					0.032
Physical activity					
Lagged	0.075	0.020	0.022	0.020	0.025
Delta	0.067*	0.022	0.019	0.030	0.023
Lagged × baseline age				−0.002	
Delta × baseline age				0.003	
Lagged × female					−0.129*
Delta × female					−0.144*
Other covariates					
Married (lagged)		0.123	−0.079	−0.083	−0.081
Married (delta)		0.179	0.098	0.095	0.094
Current working (lagged)		0.023	0.057	0.064	0.061
Current working (delta)		−0.018	0.014	0.017	0.015
Household income (lagged)		0.053	0.050	0.051	0.051
Household income (delta)		0.047*	0.047*	0.046*	0.047*
Total condition (lagged)		0.074**	0.023	0.025	0.023
Total condition (delta)		0.044**	0.022	0.024	0.022
Self-rated health (lagged)		−0.067***	−0.052***	−0.051***	−0.052***
Self-rated health (delta)		−0.055***	−0.052***	−0.051***	−0.052***
Functional capacity (lagged)		−0.028*	−0.019	−0.020	−0.020
Functional capacity (delta)		−0.012	−0.012	−0.011	−0.012
Time-constant					
For intercept					
Intercept	21.998***	22.010***	22.016***	22.019***	22.016***
Female	0.022	0.081	−0.083	−0.089	−0.082
Age	−0.079***	−0.073***	−0.031***	−0.031***	−0.032***
Education	−0.041*	−0.047*	−0.041**	−0.042**	−0.042**
Dead	−0.957***	−0.891***	−0.416***	−0.421***	−0.416***
Attrition	−0.028	−0.004	0.093	0.093	0.094
Baseline body mass index			0.755***	0.754***	0.755***
For linear slope					
Intercept	−0.054***	−0.054***	−0.049***	−0.049***	−0.049***
Female	0.012	0.012	0.012	0.012	0.012
Age	−0.003*	−0.003*	−0.004**	−0.004**	−0.004**
Education	−0.002	−0.002	−0.002	−0.003	−0.002
Dead	−0.039*	−0.039	−0.043	−0.043	−0.043

(*Continues*)

Table 3 (Continued)

	Model 1	Model 2	Model 3	Model 4	Model 5
Attrition	0.005	0.005	0.005	0.005	0.004
Baseline body mass index			−0.011***	−0.012***	−0.011***
For quadratic slope					
Intercept	−0.0036**	−0.0036*	−0.0042**	−0.0042**	−0.0042**
Female	−0.0016	−0.0016	−0.0019	−0.0019	−0.0021
Age	−0.0002	−0.0002	−0.0003	−0.0003	−0.0003
Education	0.0003	0.0003	0.0003	0.0003	0.0003
Dead	0.0014	0.0014	0.0008	0.0008	0.0008
Attrition	0.0018	0.0018	0.0019	0.0019	0.0019
Baseline body mass index			0.0002	0.0002	0.0002
Random effect (variance component)					
Intercept	7.937***	7.892***	2.493***	2.482***	2.491***
Linear slope	0.038***	0.038***	0.036***	0.035***	0.036***
Quadratic slope	0.0002*	0.0002**	0.0002*	0.0002*	0.0002*
Level 1	2.162	2.153	2.179	2.180	2.177

***$P < 0.001$. **$P < 0.01$. *$P < 0.05$.

prevalence of cigarette smoking decreases with age in older Japanese.[22] Therefore, the effect of smoking on BMI might be attenuated with age.

Initiation of both alcohol use and physical activity were associated with higher BMI in model 1; however, these associations became non-significant after adjusting for covariates and baseline BMI in models 2 and 3. In the fully adjusted model (model 3), higher household income and better self-rated health were significantly related to higher BMI over time. These factors might be proxies of alcohol use and physical activity. Indeed, drinking and physical activity were both significantly associated with higher income and better self-rated health in our samples (see Supporting information 5). This implies that people who have a high income and/or good health condition possibly drink and become physically active. Conversely, people with a low income and/or poor health condition might or must abstain from drinking and physical activity.

Previous research has reported that increases in physical activity and decreases in sedentary time are related to weight loss among Americans with obesity,[28] which is consistent with the USA study exploring the association between lifestyles and BMI trajectory.[15] However, because the proportions of overweight and obesity are lower in older Japanese adults compared with those in older Americans, the effect of physical activity on BMI might be smaller and non-significant in our samples.[16,17] In contrast, we found significant interactions between sex and physical activity (of both lagged and change terms) on BMI in model 5. This shows that the effects of physical activity and initiation/increase of physical activity on higher BMI were greater among men compared with women. A similar sex-differential pattern of association has been reported in other epidemiological studies.[14] Physical activity can increase muscle mass of older people in both sexes.[29] However, as women have more fat mass than men, physical activity can easily promote fat-burning in women.[30] This means that the fat-burning effect might be greater among women than in men; as such, physical activity could trigger an increase of muscle mass and a decrease of fat mass in women, thus obscuring a change in BMI.

This research had several limitations. First, we used self-reported height and weight, because the objectively-measured indicators were not available. People tend to overreport their height and underreport their weight, thus the level of BMI might be underestimated.[31] However, if the level of under/overreporting is relatively constant over time, the estimation of BMI trajectories over time should not be biased by misreporting. Second, because our sample consisted of only respondents aged 60 years and older, it is unclear if BMI status and changes in young and middle age moderate the effects of health behaviors on the BMI trajectory. Future studies are required to evaluate the association between health behaviors and BMI trajectory over the life-course. Third, during the period of observation (1987–2006), several health policies to promote healthy lifestyles were initiated in Japan, such as the "Active 80 Health Plan" in 1988 and "Healthy Japan 21" in 2000. Data limitations did not allow us to assess whether the health behaviors examined here and/or the trajectory of BMI might have been influenced by these policy changes. Fourth, although we treated the BMI trajectory, we did not use any nutritional and dietary indicators in the analysis. Future research should consider these effects on BMI trajectory.

A major strength of the present research lies in the longitudinal data derived from a national probability sample of older Japanese over a 19-year period. This study also considered time-varying lifestyle factors (i.e. the lagged and change terms) as independent variables. This research yields important new information regarding the complex dynamics underlying the linkage between lifestyles factors and BMI trajectory among older Japanese adults. In addition, as aforementioned, there are several differences in health behaviors between Western countries, such as the USA, and non-Western countries, such as Japan. However, compared with a similar study among older Americans, we found both similarities and dissimilarities between the USA and Japan with regard to the linkage between lifestyle factors and BMI trajectory in old age.[15] The present results suggest that there are cross-cultural differences in the linkage between lifestyle factors and BMI. Further research is clearly required not only to replicate our observations, but also to further specify the nature of the cross-cultural variations in the linkage.

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Disclosure statement

The authors declare no conflict of interest.

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's web site.

Supporting information 1. The number of study participants at each wave.

Supporting information 2. The number of observations by entry wave.

Supporting information 3. The detailed description of data analysis.

Supporting information 4. The effect of health behaviors on the trajectory of body mass index by sex (Based on model 3).

Supporting information 5. Household income and self-rated health by the status of alcohol use and physical activity.

