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Body weight and lifestyle changes under the COVID-19 pandemic in Japan: a cross-sectional study from NIPPON DATA2010

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ABSTRACT

Objectives The COVID-19 pandemic has had an impact on people's lifestyles such as causing body weight changes. This study examined associations among lifestyle changes and body weight during the COVID-19 pandemic among the Japanese population.

Design A cross-sectional study.

Setting A nationwide survey of the general Japanese population.

Participants Total participants were 2244 men and women, of which 911 young/middle-aged (30–69 years old) and 899 older adults (70 years and older) were analysed separately.

Outcome Changes in lifestyle (physical activity, dietary habits and alcohol intake) and body weight during the first wave of COVID-19 in spring 2020.

Results Under the COVID-19 pandemic, 24.1% and 10.1% of Japanese respondents reported weight gain and reduction, respectively. Multivariable-adjusted stepwise logistic regression analyses revealed that the young/middle-aged respondents in the group increased body weight, weight gain was significantly associated with decrease in physical activity (OR 4.01, 95% CI 2.83 to 5.69) and both increase (OR 5.82, 95% CI 3.85 to 8.80) and decrease (OR 2.73, 95% CI 1.52 to 4.93) in eating between meals. In the group that decreased body weight, body weight reduction was significantly associated with increase in physical activity (OR 3.66, 95% CI 1.94 to 6.90), decrease in eating between meals (OR 5.97, 95% CI 3.11 to 11.48) and both increase and decrease in alcohol intake in the young/middle age. For the older adults, body weight gain was higher in women than in men, and significantly associated with higher quartile of regional COVID-19 infection, decrease in physical activity (OR 2.98, 95% CI 1.98 to 4.49), increase in home-cooked meals and increase in eating between meals (OR 4.22, 95% CI 2.55 to 6.99). On the other hand, body weight reduction was significantly associated with decreases in physical activity (OR 2.63, 95% CI 1.62 to 4.27), home-cooked meals and eating between meals (OR 1.95, 95% CI 1.05 to 3.61) in the older adults.

Conclusion Changes in physical activity and eating between meals were associated with body weight change under the COVID-19 pandemic among Japanese.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ A nationwide survey was conducted to investigate lifestyle changes among all prefectures in Japan under the COVID-19 pandemic compared with before the pandemic.
⇒ This study examined the association of lifestyle changes with both body weight gain and loss, taking account of COVID-19 incidence in each region.
⇒ This cross-sectional study did not show a causal relationship.
⇒ Ordinal scale was used for analysis; thus, quantitative assessment was not performed.

INTRODUCTION

Energy balance, which is affected by lifestyle, is a key determinant factor of body weight changes. Physical activity increases energy expenditure and provides multiple health benefits, including body weight maintenance, as reported by WHO in 2020.[1] Unhealthy dietary habits, such as increased snacking and decreased vegetable intake, were reported to be associated with body weight gain,[2] which is related to excess energy intake. Chronic life stress influences eating patterns and food preference, thereby contributing to the development of obesity.[3]

The pandemic of the COVID-19 has had an impact on people's lifestyles around the world. In Japan, the first state of emergency was declared by the Japanese government on 7 April to reduce human-to-human contact for prevention of viral infection and was lifted on 25 March 2020.[4] Under the state of emergency, remote work was recommended, schools and universities were closed, and businesses, such as stores, restaurants and fitness facilities, were restricted. Staying at home with less chance of physical activity and

increased calorie consumption may cause an increase in weight gain and obesity; thus, increasing the risk of metabolic syndrome. Furthermore, a sedentary lifestyle is associated with undernutrition, which is a major risk factor of frailty[5] and sarcopenia,[6] especially in older adults.

The purpose of this study was to examine the associations of lifestyle changes and body weight under the spread of COVID-19 in spring 2020 among Japanese. We used the results of a questionnaire survey posted to the participants of the National Integrated Project for Prospective Observation of Non-communicable Disease and its Trends in the Aged 2010 (NIPPON DATA2010) in autumn 2020.[7]

METHODS

Participants and study design

We performed a cross-sectional study based on the design of NIPPON DATA2010,[7] a prospective cohort study initiated in 2010 to investigate factors associated with cardiovascular disease in Japan. The participants were men and women aged 20 years and older from 300 randomly selected areas throughout Japan who participated in the National Health and Nutrition Survey Japan (NHNSJ)[8] in 2010. The baseline survey was conducted at the physical examination for the NHNSJ. Written informed consent was obtained from eligible participants (n=3244). The participants had been followed up for survival and cardiovascular disease events, and an additional questionnaire asking about lifestyle changes under the COVID-19 pandemic was sent in October 2020 to 2244 participants who were alive and with known address.

A total of 1932 questionnaires out of 2244 were returned (86.1% response rate), and 122 respondents were excluded due to missing data or answering 'don't know' to any of the questions. The remaining 1810 respondents were finally analysed. They were grouped into three according to body weight change (increased, unchanged or decreased), before and during the COVID-19 pandemic in spring 2020. The participants were categorised into three groups by age as of 2020: 30–49, 50–69 and 70 years and older. All statistical analyses were performed for young/middle-aged (30–69 years old) and older adults (70 years and older) separately, as most of the older adult groups were retired; thus, changes in lifestyles under the COVID-19 pandemic may have been different.

Patient and public involvement

The patients and the public were not directly involved in the design or conduct of this study.

Questionnaire regarding body weight and lifestyle changes under the COVID-19 pandemic

In October 2020, participants were asked about changes in their lifestyle and body weight during the first state of emergency from April to May 2020, compared with before the COVID-19 pandemic. The participants were asked to write self-reported 'current body weight (in kg)' and 'change in body weight before and during the COVID-19 pandemic (April to May in 2020)'. The change in body weight was selected from six options: 'decreased ≥3 kg', 'decreased 1–3 kg', 'no change', 'increased 1–3 kg', 'increased ≥3 kg' or 'don't know'.

Change in 'total physical activity including exercise, sports, work, commute, housework, gardening, and walking' was asked. Four questions were posed about changes in dietary habits: 'frequency of eating home-cooked meals', 'frequency of eating lunch box or ready-made meals from supermarkets/convenience stores/takeaway shops/delivery service', 'frequency or amount of eating between meals' and 'frequency or amount of eating vegetables'. Participants answered each question about physical activity and dietary habits from four options: 'increased', 'unchanged', 'decreased' and 'don't know'. Change in 'frequency and/or amount of alcohol consumed' was asked and the answering options were those used for dietary habits with the addition of the option of 'non-drinker'.

Examination regarding educational attainment and infected area

Educational attainment obtained from the NIPPON DATA2010 baseline survey was used as a possible confounding variable. Participants were grouped into three: graduating from elementary and junior high school (n=356), high school (n=807) or junior college/university (n=647). Cumulative number of positive cases for COVID-19 per 100 000 people in each of 47 prefectures in Japan from the start of the disease until 1 May 2020 was calculated, and was used to explore the effects of the incidence of the area on changes in body weight and lifestyle.[9–11] The prefectures were divided into quartile groups according to incidence, and the quartile was assigned to each participant according to their address. Seven prefectures, including Tokyo, were assigned to the highest infected area (Q4, 130–316 cases/100 000, n=464); 11 prefectures assigned to Q3 (67.2–125.6 cases/100 000, n=449); 13 prefectures assigned to Q2 (34.3–66.7 cases/100 000, n=452); and 16 prefectures assigned to Q1 (0.0–32.2 cases/100 000, n=445).

Statistical analysis

Characteristics and changes in lifestyles were compared among the body weight change groups using χ^2 tests. To explore the factors associated with body weight change, multivariate logistic regressions were performed in which the objective variables were 'increased' or 'decreased' body weight, with 'unchanged' used as a reference. Each of explanatory variables, sex, age group, educational attainment, quartile of COVID-19 incidence, change in physical activity, the four dietary habits and alcohol intake were used in single regression analysis. Then, multivariable-adjusted stepwise logistic regression analyses were performed to examine the associations among body weight change and the explanatory variables.

P<0.05 (two sided) was considered significant. All statistical analyses were performed using IBM SPSS Statistics V.26 (SPSS).

RESULTS

Characteristics and changes in lifestyle according to body weight change categories

As shown in table 1, the young/middle-aged participants had a larger increase in body weight (29.9%) than the older adults (18.2%). There was no significant difference in educational status among the body weight change groups in both groups. A larger proportion of participants increased body weight in the areas with higher quartiles of COVID-19 cases in both young/middle-aged (p=0.032) and older adult (p=0.003) groups. Participants' characteristics and answers to the questionnaire according to quartiles of COVID-19 incidence are shown in online supplemental table S1. A higher proportion of participants decreased physical activity in the highly infected areas for both groups.

All lifestyle changes during the COVID-19 pandemic asked in the questionnaire were significantly different among the body weight change groups (table 1). A larger proportion of participants who answered 'decreased physical activity' increased body weight in both groups. The proportion of those who decreased body weight was the highest (25.3%) among those who increased their physical activity in the young/middle-aged group; however, this was not seen in the older adult group. A higher proportion of body weight gain was observed among participants who reported an increase in home-cooked meals, lunch box and/or ready-made meals, eating between meals and alcohol intake than those who reported a decrease in these dietary habits. For vegetable intake, more participants who reported a decrease in vegetable intake increased their body weight.

Associations among body weight change and changes in lifestyle

Results of multivariate logistic regression analyses showed significantly higher OR of body weight gain for women compared with men for both young/middle-aged and older adults (table 2). Among the young/middle-aged group, significantly higher OR of weight gain was observed for those aged 30–49 than those aged 50–69 years. ORs of body weight gain were higher in the higher quartiles of COVID-19 infection compared with Q1 in both young/middle-aged and older adults. Change in physical activity was closely related to body weight gain in both the young/middle-aged and older adults. For the young/middle-aged group, an increase and decrease in physical activity were associated with a decrease and increase in body weight, respectively. However, a decrease in physical activity was associated with both an increase and decrease in body weight in the older adults. For most of the four dietary habits asked in the questionnaire, both increase and decrease were significantly positively associated with increase and/or decrease in body weight. Especially, an increase or decrease in eating between meals was strongly and positively associated with body weight gain or body weight reduction, respectively. In the young/middle-aged group, an increase in alcohol intake was significantly positively associated with both an increase and decrease in body weight, and the decrease was significantly positively associated with body weight reduction in the young/middle-aged group. For the older adults, an increase or decrease in alcohol intake was significantly positively associated with increase and decrease in body weight, respectively.

Multivariable-adjusted stepwise logistic regression analyses among body weight and lifestyle changes

Results of multivariable-adjusted stepwise logistic regression analyses are shown in table 3. For the young/middle-aged group, sex was not an independent factor that affected body weight change, and there were no clear trends between the regional spread of COVID-19 and change in body weight. A decrease and increase in physical activity were significantly positively associated with body weight gain (OR 4.01, 95% CI 2.83 to 5.69) and body weight reduction (OR 3.66, 95% CI 1.94 to 6.90), respectively. Both an increase (OR 5.82, 95% CI 3.85 to 8.80) and decrease (OR 2.73, 95% CI 1.52 to 4.93) in eating between meals were significantly positively associated with increase in body weight. Reduced eating between meals was associated with body weight reduction (OR 5.97, 95% CI 3.11 to 11.48). Both an increase (OR 2.82, 95% CI 1.27 to 6.30) and decrease (OR 4.77, 95% CI 2.26 to 10.06) in alcohol intake were significantly positively associated with a decrease in body weight.

In the older adults, the OR of body weight gain was higher in women than that in men (OR 1.78, 95% CI 1.20 to 2.65), and a higher quartile of regional COVID-19 infection was associated with higher OR of body weight gain, but not body weight reduction. A decrease in physical activity was significantly positively associated with both weight gain (OR 2.98, 95% CI 1.98 to 4.49) and body weight reduction (OR 2.63, 95% CI 1.62 to 4.27). An increase and decrease in home-cooked meals were significantly positively associated with body weight gain and body weight reduction, respectively. Moreover, an increase and decrease in eating between meals were significantly positively associated with body weight gain and body weight reduction, respectively.

Factors entered to the model in a stepwise manner: sex, age class (for young/middle age), educational status, quartile of COVID-19 cases per 100 000 in address prefecture and changes in lifestyle (physical activity, home-cooked meals, lunch box and/or ready-made meals, eating between meals, vegetables and alcohol).

DISCUSSION

This study examined the lifestyle factors that were associated with body weight changes during the COVID-19 pandemic in Japan in spring 2020. We found that 24.1% of respondents from the whole of Japan reported weight gain, and 10.1% reported weight reduction. Body weight gain was associated with regional COVID-19 infection in the older adults but not the young/middle-aged group.

Table 1 Characteristics and changes in lifestyles during the COVID-19 pandemic in spring 2020 in Japan according to body weight change categories; Japanese men and women aged 30 years and older, NIPPON DATA2010

	Body weight change category (young/middle age) n (%)				Body weight change category (older adults) n (%)			
	Increased 272 (29.9) n (%)	Unchanged 555 (60.9) n (%)	Decreased 84 (9.2) n (%)	P value	Increased 164 (18.2) n (%)	Unchanged 637 (70.9) n (%)	Decreased 98 (10.9) n (%)	P value
Characteristics								
Sex								
Male	83 (24.2)	222 (64.7)	38 (11.1)	0.010	51 (12.8)	301 (75.6)	46 (11.6)	0.001
Female	189 (33.3)	333 (58.6)	46 (8.1)		113 (22.6)	336 (67.1)	52 (10.4)	
Age (years)								
30–49	105 (32.9)	186 (58.3)	28 (8.8)	0.334				
50–69	167 (28.2)	369 (62.3)	56 (9.5)					
≥70					164 (18.2)	637 (70.9)	98 (10.9)	
Educational status								
Junior high school	18 (30.5)	37 (62.7)	4 (6.8)	0.936	47 (15.8)	222 (74.7)	28 (9.4)	0.289
High school	111 (29.1)	233 (61.0)	38 (9.9)		82 (19.3)	298 (70.1)	45 (10.6)	
College/university	143 (30.4)	285 (60.6)	42 (8.9)		35 (19.8)	117 (66.1)	25 (14.1)	
COVID-19 cases per 100 000 in address prefecture								
Quartile 1 (lowest)	51 (23.8)	149 (69.6)	14 (6.5)	0.032	26 (10.4)	195 (78.0)	29 (11.6)	0.003
Quartile 2	66 (28.7)	134 (58.3)	30 (13.0)		41 (18.7)	159 (72.6)	19 (8.7)	
Quartile 3	81 (34.5)	134 (57.0)	20 (8.5)		52 (24.0)	144 (66.4)	21 (9.7)	
Quartile 4 (highest)	74 (31.9)	138 (59.5)	20 (8.6)		45 (21.1)	139 (65.3)	29 (13.6)	
Changes in lifestyles								
Physical activity								
Increased	16 (16.2)	58 (58.6)	25 (25.3)	<0.001	12 (19.4)	42 (67.7)	8 (12.9)	<0.001
No change	106 (20.0)	386 (72.8)	38 (7.2)		75 (12.3)	481 (78.9)	54 (8.9)	
Decreased	150 (53.2)	111 (39.4)	21 (7.4)		77 (33.9)	114 (50.2)	36 (15.9)	
Home-cooked meals								
Increased	88 (38.8)	115 (50.7)	24 (10.6)	0.005	35 (35.4)	51 (51.5)	13 (13.1)	<0.001
No change	177 (26.6)	430 (64.7)	58 (8.7)		122 (15.8)	572 (74.1)	78 (10.1)	
Decreased	7 (36.8)	10 (52.6)	2 (10.5)		7 (25.0)	14 (50.0)	7 (25.0)	
Lunch box or ready-made meals								
Increased	55 (42.6)	64 (49.6)	10 (7.8)	<0.001	20 (31.7)	32 (50.8)	11 (17.5)	<0.001
No change	175 (26.4)	432 (65.2)	56 (8.4)		118 (16.1)	539 (73.6)	75 (10.2)	
Decreased	42 (35.3)	59 (49.6)	18 (15.1)		26 (25.0)	66 (63.5)	12 (11.5)	

Continued

Table 1 Continued

	Body weight change category (young/middle age) n (%)				Body weight change category (older adults) n (%)			
	Increased 272 (29.9) n (%)	Unchanged 555 (60.9) n (%)	Decreased 84 (9.2) n (%)	P value	Increased 164 (18.2) n (%)	Unchanged 637 (70.9) n (%)	Decreased 98 (10.9) n (%)	P value
Eating between meals								
Increased	104 (64.2)	49 (30.2)	9 (5.6)	<0.001	54 (51.9)	41 (39.4)	9 (8.7)	<0.001
No change	143 (21.3)	475 (70.9)	52 (7.8)		93 (13.2)	539 (76.6)	72 (10.2)	
Decreased	25 (31.6)	31 (39.2)	23 (29.1)		17 (18.7)	57 (62.6)	17 (18.7)	
Vegetables								
Increased	45 (36.3)	59 (47.6)	20 (16.1)	<0.001	34 (26.2)	83 (63.8)	13 (10.0)	<0.001
No change	206 (27.8)	478 (64.4)	58 (7.8)		109 (15.2)	530 (73.8)	79 (11.0)	
Decreased	21 (46.7)	18 (40.0)	6 (13.3)		21 (41.2)	24 (47.1)	6 (11.8)	
Alcohol								
No drinking	114 (30.6)	231 (62.1)	27 (7.3)	<0.001	100 (19.6)	365 (71.4)	46 (9.0)	0.002
Increased	33 (39.8)	37 (44.6)	13 (15.7)		7 (35.0)	11 (55.0)	2 (10.0)	
No change	107 (27.7)	254 (65.8)	25 (6.5)		47 (15.5)	223 (73.4)	34 (11.2)	
Decreased	18 (25.7)	33 (47.1)	19 (27.1)		10 (15.6)	38 (59.4)	16 (25.0)	

The results of a χ^2 test are shown.
NIPPON DATA2010, National Integrated Project for Prospective Observation of Non-communicable Disease and its Trends in the Aged 2010.

Table 2 Associations among body weight changes and characteristics and changes in lifestyles during the COVID-19 pandemic in spring 2020 in Japan: Japanese men and women aged 30 years and older, NIPPON DATA2010

	Young/middle age (vs unchanged body weight, n=555)						Older adults (vs unchanged body weight, n=637)					
	Increased (n=272)			Decreased (n=84)			Increased (n=164)			Decreased (n=98)		
	OR	(95% CI)	P value	OR	(95% CI)	P value	OR	(95% CI)	P value	OR	(95% CI)	P value
Characteristics												
Sex												
Male	1	(Ref)		1	(Ref)		1	(Ref)		1	(Ref)	
Female	1.52	(1.11 to 2.07)	0.008	0.81	(0.51 to 1.28)	0.363	1.98	(1.38 to 2.86)	<0.001	1.01	(0.66 to 1.55)	0.953
Age (years)												
30–49	1.98	(1.38 to 2.86)	<0.001	1.01	(0.62 to 1.64)	0.974						
50–69	1	(Ref)		1	(Ref)							
Educational status												
Junior high school	1	(Ref)		1	(Ref)		1	(Ref)		1	(Ref)	
High school	0.98	(0.53 to 1.80)	0.946	1.51	(0.51 to 4.47)	0.459	1.30	(0.87 to 1.94)	0.197	1.20	(0.72 to 1.98)	0.482
College/university	1.03	(0.57 to 1.88)	0.919	1.36	(0.46 to 4.02)	0.574	1.41	(0.86 to 2.31)	0.168	1.69	(0.94 to 3.04)	0.076
COVID-19 cases per 100 000 in address prefecture												
Quartile 1 (lowest)	1	(Ref)		1	(Ref)		1	(Ref)		1	(Ref)	
Quartile 2	1.44	(0.93 to 2.22)	0.100	2.38	(1.21 to 4.68)	0.012	1.93	(1.13 to 3.30)	0.016	0.80	(0.43 to 1.49)	0.485
Quartile 3	1.77	(1.16 to 2.69)	0.008	1.59	(0.77 to 3.27)	0.209	2.71	(1.61 to 4.54)	<0.001	0.98	(0.54 to 1.79)	0.949
Quartile 4 (highest)	1.57	(1.02 to 2.40)	0.039	1.54	(0.75 to 3.17)	0.239	2.43	(1.43 to 4.12)	0.001	1.40	(0.80 to 2.45)	0.235
Changes in lifestyles												
Physical activity												
Increased	1	(0.55 to 1.82)	0.988	4.38	(2.46 to 7.78)	<0.001	1.83	(0.92 to 3.64)	0.084	1.70	(0.76 to 3.80)	0.198
No change	1	(Ref)		1	(Ref)		1	(Ref)		1	(Ref)	
Decreased	4.92	(3.55 to 6.82)	<0.001	1.92	(1.08 to 3.41)	0.026	4.33	(2.97 to 6.32)	<0.001	2.81	(1.76 to 4.49)	<0.001
Home-cooked meals												
Increased	1.86	(1.34 to 2.58)	<0.001	1.55	(0.92 to 2.60)	0.099	3.22	(2.01 to 5.16)	<0.001	1.87	(0.97 to 3.59)	0.060
No change	1	(Ref)		1	(Ref)		1	(Ref)		1	(Ref)	
Decreased	1.70	(0.64 to 4.54)	0.289	1.48	(0.32 to 6.94)	0.617	2.34	(0.93 to 5.93)	0.072	3.67	(1.44 to 9.36)	0.006
Lunch box and/or ready-made meals												
Increased	2.12	(1.42 to 3.17)	<0.001	1.21	(0.59 to 2.48)	0.612	2.85	(1.58 to 5.17)	<0.001	2.47	(1.19 to 5.11)	0.014
No change	1	(Ref)		1	(Ref)		1	(Ref)		1	(Ref)	
Decreased	1.76	(1.14 to 2.71)	0.011	2.35	(1.30 to 4.27)	0.005	1.80	(1.10 to 2.95)	0.020	1.31	(0.67 to 2.53)	0.427

Continued

Table 2 Continued

	Young/middle age (vs unchanged body weight, n=555)						Older adults (vs unchanged body weight, n=637)					
	Increased (n=272)			Decreased (n=84)			Increased (n=164)			Decreased (n=98)		
	OR	(95% CI)	P value	OR	(95% CI)	P value	OR	(95% CI)	P value	OR	(95% CI)	P value
Eating between meals												
Increased	7.05	(4.78 to 10.39)	<0.001	1.68	(0.78 to 3.61)	0.186	7.63	(4.81 to 12.11)	<0.001	1.64	(0.77 to 3.52)	0.201
No change	1	(Ref)		1	(Ref)		1	(Ref)		1	(Ref)	
Decreased	2.68	(1.53 to 4.69)	<0.001	6.78	(3.68 to 12.48)	<0.001	1.73	(0.96 to 3.10)	0.067	2.23	(1.23 to 4.05)	0.008
Vegetables												
Increased	1.77	(1.16 to 2.70)	0.008	2.79	(1.57 to 4.97)	<0.001	1.99	(1.27 to 3.12)	0.003	1.05	(0.56 to 1.97)	0.877
No change	1	(Ref)		1	(Ref)		1	(Ref)		1	(Ref)	
Decreased	2.71	(1.41 to 5.19)	0.003	2.75	(1.05 to 7.20)	0.040	4.25	(2.29 to 7.92)	<0.001	1.68	(0.66 to 4.23)	0.273
Alcohol												
No drinking	1.17	(0.85 to 1.61)	0.330	1.19	(0.67 to 2.11)	0.556	1.30	(0.88 to 1.91)	0.181	0.83	(0.51 to 1.33)	0.430
Increased	2.12	(1.26 to 3.56)	0.005	3.57	(1.68 to 7.59)	<0.001	3.02	(1.11 to 8.19)	0.030	1.19	(0.25 to 5.61)	0.823
No change	1	(Ref)		1	(Ref)		1	(Ref)		1	(Ref)	
Decreased	1.29	(0.70 to 2.40)	0.412	5.85	(2.91 to 11.76)	<0.001	1.25	(0.58 to 2.68)	0.569	2.76	(1.39 to 5.49)	0.003

The results of a multivariate logistic regression are shown.
NIPPON DATA2010, National Integrated Project for Prospective Observation of Non-communicable Disease and its Trends in the Aged 2010.

Table 3 Associations among body weight change and characteristics and changes in lifestyle from multivariable-adjusted logistic regression analyses during the COVID-19 pandemic in spring 2020; Japanese men and women aged 30 years and older, NIPPON DATA2010

	Increased body weight versus unchanged			Decreased body weight versus unchanged		
	OR	(95% CI)	P value	OR	(95% CI)	P value
Young/middle age (aged 30–69 years)						
Characteristics						
COVID-19 cases per 100 000 in address prefecture						
Quartile 1 (lowest)	1	(Ref)		1	(Ref)	
Quartile 2	1.22	(0.75 to 1.98)	0.418	3.21	(1.52 to 6.77)	0.002
Quartile 3	1.44	(0.90 to 2.30)	0.132	1.71	(0.78 to 3.76)	0.182
Quartile 4 (highest)	1.11	(0.69 to 1.79)	0.674	1.28	(0.58 to 2.83)	0.542
Changes in lifestyles						
Physical activity						
Increased	0.93	(0.50 to 1.75)	0.826	3.66	(1.94 to 6.90)	<0.001
No change	1	(Ref)		1	(Ref)	
Decreased	4.01	(2.83 to 5.69)	<0.001	1.62	(0.88 to 2.97)	0.118
Eating between meals						
Increased	5.82	(3.85 to 8.80)	<0.001	1.51	(0.68 to 3.34)	0.313
No change	1	(Ref)		1	(Ref)	
Decreased	2.73	(1.52 to 4.93)	0.001	5.97	(3.11 to 11.48)	<0.001
Alcohol						
No drinking	0.98	(0.68 to 1.40)	0.900	1.02	(0.56 to 1.85)	0.954
Increased	1.64	(0.92 to 2.92)	0.095	2.82	(1.27 to 6.30)	0.011
No change	1	(Ref)		1	(Ref)	
Decreased	0.80	(0.40 to 1.60)	0.528	4.77	(2.26 to 10.06)	<0.001
Older adults (70 years and older)						
Characteristics						
Sex						
Male	1	(Ref)		1	(Ref)	
Female	1.78	(1.20 to 2.65)	0.005	0.97	(0.63 to 1.51)	0.903
COVID-19 cases per 100 000 in address prefecture						
Quartile 1 (lowest)	1	(Ref)		1	(Ref)	
Quartile 2	1.87	(1.05 to 3.31)	0.033	0.89	(0.48 to 1.67)	0.721
Quartile 3	2.43	(1.40 to 4.23)	0.002	1.01	(0.55 to 1.87)	0.971
Quartile 4 (highest)	2.00	(1.13 to 3.54)	0.017	1.34	(0.75 to 2.39)	0.321
Changes in lifestyles						
Physical activity						
Increased	1.46	(0.70 to 3.04)	0.316	1.67	(0.73 to 3.83)	0.224
No change	1	(Ref)		1	(Ref)	
Decreased	2.98	(1.98 to 4.49)	<0.001	2.63	(1.62 to 4.27)	<0.001
Home-cooked meals						
Increased	2.02	(1.18 to 3.45)	0.010	1.48	(0.74 to 2.93)	0.267
No change	1	(Ref)		1	(Ref)	
Decreased	1.59	(0.56 to 4.53)	0.388	3.15	(1.19 to 8.32)	0.021
Eating between meals						
Increased	4.22	(2.55 to 6.99)	<0.001	1.03	(0.46 to 2.31)	0.950
No change	1	(Ref)		1	(Ref)	
Decreased	1.54	(0.83 to 2.82)	0.168	1.95	(1.05 to 3.61)	0.034

The results of a multivariable-adjusted stepwise logistic regression are shown.
Factors entered to the model in a stepwise manner: sex, age class (for young/middle age), educational status, quartile of COVID-19 cases per 100 000 in address prefecture and changes in lifestyle (physical activity, home-cooked meals, lunch box and/or ready-made meals, eating between meals, vegetables and alcohol).
NIPPON DATA2010, National Integrated Project for Prospective Observation of Non-communicable Disease and its Trends in the Aged 2010.

The present study revealed that body weight gain was strongly associated with physical activity reduction and that an increase and decrease in eating between meals were clearly related to body weight gain and reduction, respectively.

A previous study reported of Japanese patients with type 2 diabetes reported that body weight changes were positively associated with decreased exercise levels and snack consumption, resulting in increased HbA1c levels.[12] These findings suggest that the effects of lifestyle changes on body weight may be similar regardless of health severity during the COVID-19 pandemic. Previous large-scale, web-based surveys reported that mild weight gain was observed in approximately 25% of Japanese both in young/middle-aged[13] and older adults[14] who lived in urban area after the start of the COVID-19 pandemic. Our analysis showed that over 30% of adults aged 30–49 years showed body weight gain, whereas the proportion was lower in the older adults aged 70 years and older (approximately 20%). The disagreement between these previous studies and our results may be caused by different methods for conducting the survey (web based or by post) and subject area (urban or nationwide). Furthermore, younger people are substantially more active than older adults; thus, they have a higher risk of weight gain associated with staying home during the COVID-19 pandemic.

In single regression analyses, both an increase and decrease in many dietary habits were significantly positively associated with body weight increase in both young/middle-aged and older adults. In the questionnaire, we asked about changes in 'frequency or amount' of foods consumed and did not confirm the actual amount consumed; thus, some respondents may have increased the frequency but decreased the amount consumed, or may have increased their consumption of some foods and decreased other foods, which may have led to inconsistent results.

In stepwise regression analysis, many of the factors associated with body weight change in single regression analyses were not selected in the model. For young/middle-aged participants, no characteristic factor was shown to be consistently associated with body weight change. In contrast, factors associated with higher risk of body weight increase in the older adults were being female and living in area with more COVID-19-positive cases. A much higher mortality rate of COVID-19 infection in older adults has been reported[15]; thus, the older adults living in a highly infected area may have refrained from going out more than the young/middle-aged respondents. Furthermore, women may have been more careful than men.

We investigated changes in physical activity associated with body weight change both in young/middle-aged and the older adults using stepwise regression analyses. For the young/middle-aged group, decrease and increase of physical activity were associated with increase and decrease of body weight, respectively. Low levels of physical activity were an independent risk factor of obesity[16]; thus, refraining from going out may have led to lower energy expenditure and increased body weight. On the other hand, some seemed to have increased physical activity and reduced body weight. It was reported that long working hours were associated with non-exercise habits[17] and a reduced likelihood of exercise[18]; thus, teleworking may have allowed some in the young/middle-aged group to participate in exercise and reduce their body weight. In older adults, a decrease in physical activity was significantly associated with both increase and decrease in body weight. Physical activity has a protective effect against the incidence of depression,[19] which is a cause of unintentional weight loss in older adults[20]; therefore, it may be necessary to pay attention to risk of undernutrition in the older adults who reduced physical activity under the COVID-19 pandemic.

Increase and decrease in eating between meals were significantly associated with increase and decrease in body weight in both the young/middle-aged and older adult groups, respectively. A previous study in Europe reported increased snacking during lockdown and quarantine due to COVID-19,[21–23] which is similar to the present study. Among the young/middle-aged participants, decrease in eating between meals was also associated with body weight increase; thus, they may be consuming more calorific meals. For the young/middle-aged group, the other three dietary habits were not selected in the regression model. Eating between meals may have had a bigger impact on total energy intake than eating home-cooked or ready-made meals, or eating vegetables. Increased time staying at home may have increased the chance of eating between meals, which may lead to an increase in body weight; thus, frequent checks of body weight and diet, especially for those eating between meals, are recommended.

For older adults, an increase and decrease in home-cooked meals were also significantly associated with an increase and decrease in body weight, respectively. During the COVID-19 pandemic, the operations of supermarkets and restaurants were restricted, and the proportion of those who reported an increase in lunch box or ready-made meal consumption was lower in older adults (7.0%) than young/middle-aged respondents (14.2%). There is a possibility that some older adults had difficulties buying foods at stores or using delivery services, and this resulted in a decrease in home-cooked meals and insufficient energy intake.

Drinking opportunities outside the home were reduced due to the closure of bars and restaurants during the COVID-19 pandemic. Both an increase and decrease in alcohol intake among the young/middle-aged group were significantly associated with body weight reduction in this study. Those who decreased alcohol intake and decreased body weight may have had reduced opportunities to eat side dishes and snacks due to restaurant and bar closures. On the other hand, those who increased alcohol and decreased body weight may have had inadequate nutrition. For young/middle-aged participants, the difference between participants who reported an increase

(9.1%) and decrease (7.7%) in alcohol intake was small. Attention should be paid to increases in alcohol intake even among people staying at home.

There were several limitations to this study. A causal relationship among body weight and lifestyle changes was not assessed as this was a cross-sectional study. Moreover, an ordinal scale was used for analysis, and so quantitative assessment of physical activity or dietary intake was not performed. Unlike previous studies, our study did not measure metabolic and physiological conditions such as glycaemic data,[12 24] body composition[12 24] and frailty.[25]

CONCLUSION

Decrease in physical activity and increase in eating between meals were significantly associated with increase in body weight during the COVID-19 pandemic in Japan. Attention should be paid to appropriate physical activity and dietary intake, especially avoiding excessive snacking.

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Table S1. Characteristics and changes in lifestyles during the COVID-19 pandemic in spring 2020 in Japan according to COVID-19 cases per 100,000 in address prefecture categories

	COVID-19 cases per 100,000 in address prefecture (young/middle-age, N=911)					COVID-19 cases per 100,000 in address prefecture (older adults, N=899)				
	Q1 (lowest) (n=214)	Q2 (n=230)	Q3 (n=235)	Q4 (highest) (n=232)	*P*	Q1 (lowest) (n=250)	Q2 (n=219)	Q3 (n=217)	Q4 (highest) (n=213)	*P*
	n (%)	n (%)	n (%)	n (%)		n (%)	n (%)	n (%)	n (%)	
Sex										
Male	79 (23.0)	84 (24.5)	89 (25.9)	91 (26.5)	0.935	116 (29.1)	91 (22.9)	90 (22.6)	101 (25.4)	0.447
Female	135 (23.8)	146 (25.7)	146 (25.7)	141 (24.8)		134 (26.7)	128 (25.5)	127 (25.3)	112 (22.4)	
Age (years)										
30 - 49	72 (22.6)	82 (25.7)	91 (28.5)	74 (23.2)						
50 - 69	142 (24.0)	148 (25.0)	144 (24.3)	158 (26.7)	0.452					
≥ 70						250 (27.8)	219 (24.4)	217 (24.1)	213 (23.7)	
Educational status										
Junior high school	20 (33.9)	13 (22.0)	14 (23.7)	12 (20.3)		99 (33.3)	80 (26.9)	53 (17.8)	65 (21.9)	
High school	98 (25.7)	103 (27.0)	90 (23.6)	91 (23.8)	0.143	113 (26.6)	103 (24.2)	115 (27.1)	94 (22.1)	0.003
College/university	96 (20.4)	114 (24.3)	131 (27.9)	129 (27.4)		38 (21.5)	36 (20.3)	49 (27.7)	54 (30.5)	
Physical activity*										
Increased	22 (10.3)	16 (7.0)	26 (11.1)	35 (15.1)		23 (9.2)	18 (8.2)	14 (6.5)	7 (3.3)	
No change	145 (67.8)	145 (63.0)	124 (52.8)	116 (50.0)	<0.001	174 (69.6)	155 (70.8)	141 (65.0)	140 (65.7)	0.027
Decreased	47 (22.0)	69 (30.0)	85 (36.2)	81 (34.9)		53 (21.2)	46 (21.0)	62 (28.6)	66 (31.0)	
Home cooked meals*										
Increased	36 (16.8)	61 (26.5)	64 (27.2)	66 (28.4)		25 (10.0)	28 (12.8)	20 (9.2)	26 (12.2)	
No change	169 (79.0)	165 (71.7)	167 (71.1)	164 (70.7)	0.017	214 (85.6)	189 (86.3)	193 (88.9)	176 (82.6)	0.088
Decreased	9 (4.2)	4 (1.7)	4 (1.7)	2 (0.9)		11 (4.4)	2 (0.9)	4 (1.8)	11 (5.2)	
Lunch box and/or ready-made meals*										
Increased	26 (12.1)	34 (14.8)	39 (16.6)	30 (12.9)		14 (5.6)	11 (5.0)	19 (8.8)	19 (8.9)	
No change	165 (77.1)	168 (73.0)	168 (71.5)	162 (69.8)	0.308	209 (83.6)	186 (84.9)	172 (79.3)	165 (77.5)	0.088
Decreased	23 (10.7)	28 (12.2)	28 (11.9)	40 (17.2)		27 (10.8)	22 (10.0)	26 (12.0)	29 (13.6)	
Eating between meals*										
Increased	27 (12.6)	40 (17.4)	44 (18.7)	51 (22.0)		17 (6.8)	23 (10.5)	31 (14.3)	33 (15.5)	
No change	168 (78.5)	170 (73.9)	176 (74.9)	156 (67.2)	0.113	205 (82.0)	179 (81.7)	164 (75.6)	156 (73.2)	0.047
Decreased	19 (8.9)	20 (8.7)	15 (6.4)	25 (10.8)		28 (11.2)	17 (7.8)	22 (10.1)	24 (11.3)	
Vegetables*										
Increased	28 (13.1)	30 (13.0)	22 (9.4)	44 (19.0)		34 (13.6)	34 (15.5)	29 (13.4)	33 (15.5)	
No change	174 (81.3)	188 (81.7)	201 (85.5)	179 (77.2)	0.130	205 (82.0)	171 (78.1)	176 (81.1)	166 (77.9)	0.897
Decreased	12 (5.6)	12 (5.2)	12 (5.1)	9 (3.9)		11 (4.4)	14 (6.4)	12 (5.5)	14 (6.6)	
Alcohol*										
No drinking	74 (34.6)	106 (46.1)	92 (39.1)	100 (43.1)		150 (60.0)	134 (61.2)	119 (54.8)	108 (50.7)	
Increased	16 (7.5)	19 (8.3)	24 (10.2)	24 (10.3)	0.175	5 (2.0)	5 (2.3)	5 (2.3)	5 (2.3)	0.296
No change	107 (50.0)	93 (40.4)	96 (40.9)	90 (38.8)		78 (31.2)	69 (31.5)	71 (32.7)	86 (40.4)	
Decreased	17 (7.9)	12 (5.2)	23 (9.8)	18 (7.8)		17 (6.8)	11 (5.0)	22 (10.1)	14 (6.6)	

COVID-19, coronavirus disease 2019. The results of a chi-square test are shown. * Percentages to total of columns