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Association among body weight changes and lifestyle changes under COVID-19 pandemic in Japan: A cross-sectional study from NIPPON DATA2010

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2022-063213
Article Type:	Original research
Date Submitted by the Author:	25-Mar-2022
Complete List of Authors:	<p>Taniguchi, Hirokazu; Kyoto Prefectural University, Division of Applied Life Sciences, Graduate School of Life and Environmental Sciences Okuda, Nagako; Kyoto Prefectural University, Division of Applied Life Sciences, Graduate School of Life and Environmental Sciences Arima, Hisatomi; Fukuoka University, Department of Preventative Medicine and Public Health Satoh, Atsushi; Fukuoka University, Department of Preventive Medicine and Public Health Abe, Makiko; Fukuoka University, Department of Preventative Medicine and Public Health Nishi, Nobuo; National Institute of Health and Nutrition, International Center for Nutrition and Information Higashiyama, Aya; Wakayama Medical University, Department of Hygiene Suzuki, Harumitsu; Wakayama Medical University, Department of Hygiene Ohkubo, Takayoshi; Teikyo University, Department of Hygiene and Public Health Kadota, Aya; Shiga University of Medical Science, NCD Epidemiologic Research Center Miura, katsuyuki; Shiga University of Medical Science, NCD Epidemiologic Research Center Ueshima, Hirotsugu; Shiga University of Medical Science, NCD Epidemiologic Research Center Okayama, Akira; Research Institute of Strategy for Prevention</p>
Keywords:	COVID-19, PUBLIC HEALTH, EPIDEMIOLOGY

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- 1 Association among body weight changes and lifestyle changes under COVID-19 pandemic in Japan:
2 A cross-sectional study from NIPPON DATA2010
3
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27 26 **Keywords:** COVID-19, EPIDEMIOLOGY, PUBLIC HEALTH
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30 27
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33 28 **Word count:** 2694
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6 29 **Abstract**
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12 31 **Objectives** The coronavirus disease 2019 (COVID-19) pandemic has had an impact on people's
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15 32 lifestyles such as causing body weight changes. This study examined associations among lifestyle
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18 33 changes and body weight during the COVID-19 pandemic among the Japanese population.
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21 34 **Design** A cross-sectional study.
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24 35 **Setting** A nationwide survey of the general Japanese population.
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27 36 **Participants** Total participants were 2,244 men and women, of which 911 adults (30-69 years old)
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30 37 and 899 elderly (70 years and older) were analyzed separately.
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33 38 **Outcome** Changes in lifestyle (physical activity, dietary habits, and alcohol intake) and body weight
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36 39 during the first wave of COVID-19 in spring 2020.
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39 40 **Results** Under the COVID-19 pandemic, 24.1% and 10.1% of Japanese respondents reported weight
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42 41 gain and reduction, respectively. Multivariable adjusted stepwise logistic regression analyses revealed
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45 42 that in the adults for group that increased body weight, weight gain was significantly associated with
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48 43 decrease in physical activity (OR 4.01 [2.83-5.69]) and both increase (OR 5.82 [3.85-8.80]) and
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51 44 decrease (OR 2.73 [1.52-4.93]) in eating between meals. On the other hand, in the group that decreased
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54 45 body weight, body weight reduction was significantly associated with increase in physical activity
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57 46 (OR 3.66 [1.94-6.90]), decrease in eating between meals (OR 5.98 [3.11-11.48]), and both increase
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6 47 and decrease in alcohol intake in the adults. For the elderly, body weight gain was higher in women
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9 48 than in men, and significantly associated with higher quartile of regional COVID-19 infection,
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11
12 49 decrease in physical activity (OR 2.98 [1.98-4.49]), increase in home-cooked meals, and increase in
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14
15 50 eating between meals (OR 4.22 [2.55-6.99]). On the other hand, body weight reduction was
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18 51 significantly associated with decreases in physical activity (OR 2.63 [1.62-4.27]), home-cooked meals,
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20
21 52 and eating between meals (OR 1.95 [1.05-3.61]) in the elderly.

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24 53 **Conclusion** Changes in physical activity and eating between meals were associated with body weight
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27 54 change under the COVID-19 pandemic among Japanese.

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33 56 **Strengths and limitations of this study**

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36 57 • This study is the first examination regarding associations among lifestyle changes and body
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39 58 weight under the COVID-19 pandemic in a representative Japanese population.
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42 59 • A nationwide survey was conducted among all prefectures in Japan.
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45 60 • This cross-sectional study did not show a causal relationship among body weight and lifestyle
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48 61 changes.
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51 62 • Ordinal scale was used for analysis; thus, quantitative assessment was not performed.

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64 INTRODUCTION

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66 The pandemic of the coronavirus disease 2019 (COVID-19) has had an impact on people's lifestyles
67 around the world. In Japan, the first state of emergency was declared by the Japanese government on
68 April 7 to reduce human-to-human contact for prevention of viral infection, and was lifted on March
69 25, 2020 ¹. Under the state of emergency, remote work was recommended, schools and universities
70 were closed, and businesses, such as stores, restaurants, and fitness facilities, were restricted. Staying
71 at home with less chance of physical activity and increased calorie consumption may cause an increase
72 in weight gain and obesity; thus, increasing the risk of metabolic syndrome. Furthermore, a sedentary
73 lifestyle is associated with undernutrition, which is a major risk factor of frailty ² and sarcopenia ³,
74 especially in elderly individuals.

75 The purpose of this study was to examine the associations of lifestyle changes and body
76 weight under the spread of COVID-19 in spring 2020 among Japanese. We used the results of a
77 questionnaire survey posted to the participants of the National Integrated Project for Prospective
78 Observation of Non-communicable Disease and its Trends in the Aged 2010 (NIPPON DATA2010)
79 in autumn 2020 ⁴.

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81 METHODS

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6 82 *Study population*
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12 84 We performed a cross-sectional study based on the design of NIPPON DATA2010 ⁴, a prospective

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15 85 cohort study initiated in 2010 to investigate factors associated with cardiovascular disease in Japan.

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18 86 The participants were men and women aged 20 years and older from 300 randomly selected areas

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21 87 throughout Japan who participated in the National Health and Nutrition Survey Japan (NHNSJ) ⁵ in

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24 88 2010. The baseline survey was conducted at the physical examination for the NHNSJ. Written

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27 89 informed consent was obtained from eligible participants (n = 3,244). The participants had been

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30 90 followed up for survival and cardiovascular disease events, and an additional questionnaire asking

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33 91 about lifestyle changes under the COVID-19 pandemic was sent in October 2020 to 2,244 participants

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36 92 who were alive and with known address.

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39 93 The study was approved by the Institutional Review Board of Shiga University of Medical

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42 94 Science (R2010-029). The Ethics Committee of Kyoto Prefectural University also approved analysis

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45 95 of the anonymized dataset (228).

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51 97 *Patient and Public Involvement*
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57 99 Patients and the public were not directly involved in the design or conduct of this study.
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6 100 *Questionnaire*
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12 102 In October 2020, participants were asked about changes in their lifestyle and body weight during the
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15 103 first state of emergency from April to May 2020, compared with before the COVID-19 pandemic. The
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18 104 participants were asked to write self-reported “current body weight (in kg)” and “change in body
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21 105 weight before and during the COVID-19 pandemic (April to May in 2020)”. The change in body
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24 106 weight was selected from six options: “decreased ≥ 3 kg”, “decreased 1-3 kg”, “no change”, “increased
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27 107 1-3 kg”, “increased ≥ 3 kg”, or “don’t know”.
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30 108 Change in “total physical activity including exercise, sports, work, commute, housework,
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33 109 gardening, and walking.” was asked. Four questions were posed about changes in dietary habits:
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36 110 “frequency of eating home-cooked meals”, “frequency of eating lunch box or ready-made meals from
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39 111 supermarkets/convenience stores/takeaway shops/delivery service”, “frequency or amount of eating
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42 112 between meals”, and “frequency or amount of eating vegetables”. Participants answered each question
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45 113 from four options: “increased”, “unchanged”, “decreased”, and “don’t know”. Change in “frequency
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48 114 and/or amount of alcohol consumed” was asked and the answering options were those used for dietary
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51 115 habits plus “non-drinker”.
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57 117 *Other variables*
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119 Educational attainment obtained from the NIPPON DATA2010 baseline survey was used as a possible
120 confounding variable. Participants were grouped into three groups: graduating from elementary and
121 junior high school (n = 356), high school (n = 807), or junior college/university (n = 647). Cumulative
122 number of positive cases for COVID-19 per 100,000 people in each of 47 prefectures in Japan from
123 the start of the disease until May 1, 2020 were calculated, and was used to explore the effects of the
124 incidence of the area on changes in body weight and lifestyle ⁶⁻⁸. The prefectures were divided into
125 quartile groups according to incidence, and the quartile was assigned to each participant according to
126 their address. Seven prefectures, including Tokyo, were assigned to the highest infected area (Q4, 130-
127 316 cases/100,000, n = 464), 11 prefectures assigned to Q3 (67.2-125.6 cases/100,000, n = 449); 13
128 prefectures assigned to Q2 (34.3-66.7 cases/100,000, n = 452), and 16 prefectures assigned to Q1 (0.0-
129 32.2 cases/100,000, n = 445).

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131 *Statistical analysis*

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133 A total of 1,932 questionnaires out of 2,244 were returned (86.1% response rate), and 122 patients
134 were excluded due to missing data or answering “don’t know” to any of the questions. The remaining
135 1,810 participants were finally analyzed. They were grouped into three groups according to body

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6 136 weight change (increased, unchanged, or decreased), before and during the COVID-19 pandemic in
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9 137 spring 2020. The age of the participants as of 2020 were categorized into three groups: 30-49 years,
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12 138 50-69 years, and 70 years and older. All statistical analysis were performed for adults (30-69 years
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15 139 old) and elderly (70 years and older) separately, as most of the elderly group were retired; thus,
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18 140 changes in lifestyles under the COVID-19 pandemic may have been different.
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21 141 Characteristics and changes in lifestyles were compared among the body weight change
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24 142 groups using chi-squared tests. To explore the factors associated with body weight change,
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27 143 multivariate logistic regressions were performed in which the objective variables were “increased” or
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30 144 “decreased” body weight, with “unchanged” used as a reference. Each of explanatory variables, sex,
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33 145 age group, educational attainment, quartile of COVID-19 incidence, change in physical activity, the
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36 146 four dietary habits, and alcohol intake, were used in single regression analysis. Then, multivariable
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39 147 adjusted stepwise logistic regression analyses were performed to examine the associations among
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42 148 body weight change and the explanatory variables.
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45 149 $P < 0.05$ (two-sided) was considered significant. All statistical analyses were performed
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48 150 using IBM SPSS Statistics 26 (SPSS Inc., Chicago, IL., USA).
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52 53 54 152 **RESULTS**

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6 154 *Characteristics and changes in lifestyle according to body weight change categories*
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12 156 As shown in Table 1, the adult participants had a larger increase in body weight (29.9%)
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15 157 than the elderly participants (18.2%). There was a no significant difference in educational status
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18 158 among the body weight change groups in both groups. A larger proportion of participants increased
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21 159 body weight in the areas with higher quartiles of COVID-19 cases in both adults ($P = 0.032$) and
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24 160 elderly ($P = 0.003$) groups. Participants' characteristics and answers to the questionnaire according to
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27 161 quartiles of COVID-19 incidence are shown in Table S1. More participants decreased physical activity
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30 162 in the highly infected areas for both groups.
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33 163 All lifestyle changes during the COVID-19 pandemic asked in the questionnaire were
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36 164 significantly different among the body weight change groups (Table 1). More participants who
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39 165 answered "decreased physical activity" increased body weight in both groups. The proportion of those
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42 166 who decreased body weight was the highest (25.3%) among those that increased their physical activity
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45 167 in the adult group; however, this was not seen in the elderly group. A higher proportion of body weight
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48 168 gain was observed among participants who reported an increase in home-cooked meals, lunch box
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51 169 and/or ready-made meals, eating between meals, and alcohol intake than those that reported a decrease
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54 170 in these dietary habits. For vegetable intake, more participants that reported a decrease in vegetable
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57 171 intake increased their body weight.
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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

Characteristics	Body weight change category (adults), n (%)				Body weight change category (elderly), n (%)									
	Increased 272 (29.9)		Unchanged 555 (60.9)		Decreased 84 (9.2)		P	Increased 164 (18.2)		Unchanged 637 (70.9)		Decreased 98 (10.9)		P
	n	(%)	n	(%)	n	(%)		n	(%)	n	(%)	n	(%)	
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)	
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)	

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

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6 172 *Associations among body weight change and changes in lifestyle*
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12 174 Results of multivariate logistic regression analyses showed significantly higher OR of body weight
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15 175 gain for women compared to men for both adults and elderly (Table 2). Among the adults, significantly
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18 176 higher OR of weight gain was observed for those aged 30-49 than those aged 50-69 years. ORs of
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21 177 body weight gain were higher in the higher quartiles of COVID-19 infection compared to Q1 in both
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24 178 adults and elderly. Change in physical activity was closely related to body weight gain in both the
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27 179 adult and elderly participants. For adults, an increase and decrease in physical activity were associated
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30 180 with a decrease and increase in body weight, respectively. However, a decrease in physical activity
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33 181 was associated with both an increase and decrease in body weight in the elderly. For most of the four
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36 182 dietary habits asked in the questionnaire, both increase and decrease were significantly positively
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39 183 associated with increase and/or decrease in body weight. In the adults, an increase in alcohol intake
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42 184 was significantly positively associated with both an increase and decrease in body weight, and the
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45 185 decrease was significantly positively associated with body weight reduction in the adults. For the
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48 186 elderly, an increase or decrease in alcohol intake was significantly positively associated with increase
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51 187 and decrease in body weight, respectively.
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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

	Adults (vs. unchanged body weight, n=555)						Elderly (vs. unchanged body weight, n=637)					
	Increased (n=272)			Decreased (n=84)			Increased (n=164)			Decreased (n=98)		
	OR	(95%CI)	P	OR	(95%CI)	P	OR	(95%CI)	P	OR	(95%CI)	P
Characteristics												
Sex												
Male	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Female	1.52	(1.11-2.07)	0.008	0.81	(0.51-1.28)	0.363	1.98	(1.38-2.86)	<0.001	1.01	(0.66-1.55)	0.953
Age (years)												
30 - 49	1.98	(1.38-2.86)	<0.001	1.01	(0.62-1.64)	0.974						
50 - 69	1.00	(Ref)		1.00	(Ref)							
Educational status												
Junior high school	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
High school	0.98	(0.53-1.80)	0.946	1.51	(0.51-4.47)	0.459	1.30	(0.87-1.94)	0.197	1.20	(0.72-1.98)	0.482
College/university	1.03	(0.57-1.88)	0.919	1.36	(0.46-4.02)	0.574	1.41	(0.86-2.31)	0.168	1.69	(0.94-3.04)	0.076
COVID-19 cases per 100,000 in address prefecture												
Quartile 1 (lowest)	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Quartile 2	1.44	(0.93-2.22)	0.100	2.38	(1.21-4.68)	0.012	1.93	(1.13-3.30)	0.016	0.80	(0.43-1.49)	0.485
Quartile 3	1.77	(1.16-2.69)	0.008	1.59	(0.77-3.27)	0.209	2.71	(1.61-4.54)	<0.001	0.98	(0.54-1.79)	0.949
Quartile 4 (highest)	1.57	(1.02-2.40)	0.039	1.54	(0.75-3.17)	0.239	2.43	(1.43-4.12)	0.001	1.40	(0.80-2.45)	0.235
Changes in lifestyles												
Physical activity												
Increased	1.00	(0.55-1.82)	0.988	4.38	(2.46-7.78)	<0.001	1.83	(0.92-3.64)	0.084	1.70	(0.76-3.80)	0.198
No change	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Decreased	4.92	(3.55-6.82)	<0.001	1.92	(1.08-3.41)	0.026	4.33	(2.97-6.32)	<0.001	2.81	(1.76-4.49)	<0.001
Home cooked meals												
Increased	1.86	(1.34-2.58)	<0.001	1.55	(0.92-2.60)	0.099	3.22	(2.01-5.16)	<0.001	1.87	(0.97-3.59)	0.060
No change	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Decreased	1.70	(0.64-4.54)	0.289	1.48	(0.32-6.94)	0.617	2.34	(0.93-5.93)	0.072	3.67	(1.44-9.36)	0.006
Lunch box and/or ready-made meals												
Increased	2.12	(1.42-3.17)	<0.001	1.21	(0.59-2.48)	0.612	2.85	(1.58-5.17)	<0.001	2.47	(1.19-5.11)	0.014
No change	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Decreased	1.76	(1.14-2.71)	0.011	2.35	(1.30-4.27)	0.005	1.80	(1.10-2.95)	0.020	1.31	(0.67-2.53)	0.427
Eating between meals												
Increased	7.05	(4.78-10.39)	<0.001	1.68	(0.78-3.61)	0.186	7.63	(4.81-12.11)	<0.001	1.64	(0.77-3.52)	0.201
No change	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Decreased	2.68	(1.53-4.69)	<0.001	6.78	(3.68-12.48)	<0.001	1.73	(0.96-3.10)	0.067	2.23	(1.23-4.05)	0.008
Vegetables												
Increased	1.77	(1.16-2.70)	0.008	2.79	(1.57-4.97)	<0.001	1.99	(1.27-3.12)	0.003	1.05	(0.56-1.97)	0.877
No change	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Decreased	2.71	(1.41-5.19)	0.003	2.75	(1.05-7.20)	0.040	4.25	(2.29-7.92)	<0.001	1.68	(0.66-4.23)	0.273
Alcohol												
No drinking	1.17	(0.85-1.61)	0.330	1.19	(0.67-2.11)	0.556	1.30	(0.88-1.91)	0.181	0.83	(0.51-1.33)	0.430
Increased	2.12	(1.26-3.56)	0.005	3.57	(1.68-7.59)	<0.001	3.02	(1.11-8.19)	0.030	1.19	(0.25-5.61)	0.823
No change	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Decreased	1.29	(0.70-2.40)	0.412	5.85	(2.91-11.76)	<0.001	1.25	(0.58-2.68)	0.569	2.76	(1.39-5.49)	0.003

CI, confidence interval; COVID-19, coronavirus disease 2019; OR, odds ratio.

The results of a multivariate logistic regression are shown.

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6 188 *Multivariable-adjusted Stepwise Logistic Regression Analyses among Body Weight and Lifestyle*

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9 189 *Changes*

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15 191 Factors that affect body weight change were examined using a multivariable-adjusted model, in which

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18 192 characteristics (sex, age class [for adults, 30-49 years, and 50-69 years], and educational status, and

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21 193 quartile groups of COVID-19 cases) and changes in lifestyles (physical activity, dietary habits, and

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24 194 alcohol intake) were entered in a stepwise manner. Results are shown in Table 3.

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27 195 For the adults, sex was not an independent factor that affected body weight change, and

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30 196 there were no clear trends between the regional spread of COVID-19 and change in body weight. A

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33 197 decrease and increase in physical activity were significantly positively associated with body weight

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36 198 gain (OR 4.01 [2.83-5.69]) and body weight reduction (OR 3.66 [1.94-6.90]), respectively. Both an

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39 199 increase (OR 5.82 [3.85-8.80]) and decrease (OR 2.73 [1.52-4.93]) in eating between meals were

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42 200 significantly positively associated with increase in body weight. Reduced eating between meals was

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45 201 associated with body weight reduction (OR 5.98 [3.11-11.48]). Both an increase (OR 2.82 [1.27-6.30])

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48 202 and decrease (OR 4.77 [2.26-10.06]) in alcohol intake were significantly positively associated with a

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51 203 decrease in body weight.

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54 204 In the elderly participants, the OR of body weight gain was higher in women than that in

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57 205 men (OR 1.78 [1.20-2.65]), and a higher quartile of regional COVID-19 infection was associated with

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6 206 higher OR of body weight gain, but not body weight reduction. A decrease in physical activity was
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9 207 significantly positively associated with both weight gain (OR 2.98 [1.98-4.49]) and body weight
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12 208 reduction (OR 2.63 [1.62-4.27]). An increase and decrease in home-cooked meals were significantly
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15 209 positively associated with body weight gain and body weight reduction, respectively. Moreover, an
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18 210 increase and decrease in eating between meals were significantly positively associated with body
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21 211 weight gain and body weight reduction, respectively.
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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 vs. unchanged			Decreased body weight vs. unchanged		
	OR	(95%CI)	<i>P</i>	OR	(95%CI)	<i>P</i>
Adults (aged 30-59 years)						
Characteristics						
COVID-19 cases per 100,000 in address prefecture						
Quartile 1 (lowest)	1.00	(Ref)		1.00	(Ref)	
Quartile 2	1.22	(0.75-1.98)	0.418	3.21	(1.52-6.77)	0.002
Quartile 3	1.44	(0.90-2.30)	0.132	1.71	(0.78-3.76)	0.182
Quartile 4 (highest)	1.11	(0.69-1.79)	0.674	1.28	(0.58-2.83)	0.542
Changes in lifestyles						
Physical activity						
Increased	0.93	(0.50-1.75)	0.826	3.66	(1.94-6.90)	<0.001
No change	1.00	(Ref)		1.00	(Ref)	
Decreased	4.01	(2.83-5.69)	<0.001	1.62	(0.88-2.97)	0.118
Eating between meals						
Increased	5.82	(3.85-8.80)	<0.001	1.51	(0.68-3.34)	0.313
No change	1.00	(Ref)		1.00	(Ref)	
Decreased	2.73	(1.52-4.93)	0.001	5.97	(3.11-11.48)	<0.001
Alcohol						
No drinking	0.98	(0.68-1.40)	0.900	1.02	(0.56-1.85)	0.954
Increased	1.64	(0.92-2.92)	0.095	2.82	(1.27-6.30)	0.011
No change	1.00	(Ref)		1.00	(Ref)	
Decreased	0.80	(0.40-1.60)	0.528	4.77	(2.26-10.1)	<0.001
Elderly (70 years and older)						
Characteristics						
Sex						
Male	1.00	(Ref)		1.00	(Ref)	
Female	1.78	(1.20-2.65)	0.005	0.97	(0.63-1.51)	0.903
COVID-19 cases per 100,000 in address prefecture						
Quartile 1 (lowest)	1.00	(Ref)		1.00	(Ref)	
Quartile 2	1.87	(1.05-3.31)	0.033	0.89	(0.48-1.67)	0.721
Quartile 3	2.43	(1.40-4.23)	0.002	1.01	(0.55-1.87)	0.971
Quartile 4 (highest)	2.00	(1.13-3.54)	0.017	1.34	(0.75-2.39)	0.321
Changes in lifestyles						
Physical activity						
Increased	1.46	(0.70-3.04)	0.316	1.67	(0.73-3.83)	0.224
No change	1.00	(Ref)		1.00	(Ref)	
Decreased	2.98	(1.98-4.49)	<0.001	2.63	(1.62-4.27)	<0.001
Home cooked meals						
Increased	2.02	(1.18-3.45)	0.010	1.48	(0.74-2.93)	0.267
No change	1.00	(Ref)		1.00	(Ref)	
Decreased	1.59	(0.56-4.53)	0.388	3.15	(1.19-8.32)	0.021
Eating between meals						
Increased	4.22	(2.55-6.99)	<0.001	1.03	(0.46-2.31)	0.950
No change	1.00	(Ref)		1.00	(Ref)	
Decreased	1.54	(0.83-2.82)	0.168	1.95	(1.05-3.61)	0.034

CI, confidence interval; COVID-19, coronavirus disease 2019; OR, odds ratio.

The results of a multivariable-adjusted stepwise logistic regression are shown.

Factors entered to the model in a stepwise manner; sex, age class (for adults), 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).

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6 213 **DISCUSSION**
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12 215 This study examined the lifestyle factors that were associated with body weight changes during the
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15 216 COVID-19 pandemic in Japan in spring 2020. We found that 24.1% of respondents from the whole of
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18 217 Japan reported weight gain, and 10.1% reported weight reduction. Body weight gain was associated
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21 218 with regional COVID-19 infection in the elderly group but not the adult group. The questionnaire
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24 219 revealed that body weight gain was strongly associated with physical activity reduction and that an
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27 220 increase and decrease in eating between meals were clearly related to body weight gain and reduction,
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30 221 respectively.
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33 222 A previous web-based survey reported that mild weight gain was observed in approximately
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36 223 25% of Japanese under 65 years old⁹. Our analysis showed that over 30% of adults aged 30-49 years
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39 224 showed body weight gain, whereas the proportion was lower in the elderly aged 70 years and older
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42 225 (approximately 20%). Younger people are substantially more active than elderly people; thus, they
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45 226 had a higher risk of weight gain associated with staying home during the COVID-19 pandemic.
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48 227 In single regression analyses, both an increase and decrease in many dietary habits were
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51 228 significantly positively associated with body weight increase in both adults and elderly. In the
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54 229 questionnaire we asked about changes in "frequency or amount" of foods consumed and did not
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57 230 confirm the actual amount consumed; thus, some respondents may have increased the frequency but
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6 231 decreased the amount consumed, or may have increased their consumption of some foods and
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9 232 decreased other foods, which may have led to inconsistent results.
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12 233 In stepwise regression analysis, many of the factors associated with body weight change in
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15 234 single regression analyses were not selected in the model. For adult participants, no characteristic
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18 235 factor was shown to be consistently associated with body weight change. For elderly people, being
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21 236 female and living in area with more COVID-19 positive cases were associated with higher risk of body
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24 237 weight increase. A much higher mortality rate of COVID-19 infection in older adults has been
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27 238 reported¹⁰; thus, the elderly respondents living in a highly infected area may have refrained from going
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30 239 out more than the adults. Furthermore, women may have been more careful than men.
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33 240 We investigated changes in physical activity associated with body weight change both in
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36 241 adults and the elderly using stepwise regression analyses. For adults, decrease and increase of physical
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39 242 activity were associated with increase and decrease of body weight, respectively. Low levels of
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42 243 physical activity were an independent risk factor of obesity ¹¹; thus, refraining from going out may
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45 244 have led to lower energy expenditure and increased body weight. On the other hand, some seemed to
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48 245 have increased physical activity and reduced body weight. It was reported that long working hours
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51 246 was associated with non-exercise habits ¹² and a reduced likelihood of exercise ¹³; thus, teleworking
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54 247 may have allowed some adults to participate in exercise and reduce their body weight. In elderly
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57 248 participants, a decrease in physical activity was significantly associated with both increase and
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6 249 decrease in body weight. Physical activity has a protective effect against the incidence of depression
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9 250 ¹⁴, which is a cause of unintentional weight loss in elderly individuals ¹⁵; therefore, it may be necessary
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12 251 to pay attention to risk of undernutrition in the elderly who reduced physical activity under the
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15 252 COVID-19 pandemic.

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18 253 Increase and decrease in eating between meals were significantly associated with increase
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21 254 and decrease in body weight in both the adult and elderly groups. A previous study in Europe reported
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24 255 increased snacking during lockdown and quarantine due to COVID-19 ¹⁶⁻¹⁸, which is similar to the
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27 256 present study. Among the adult participants, decrease in eating between meals was also associated
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30 257 with body weight increase; thus, they may be consuming more calorific meals. For adults, the other
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33 258 three dietary habits were not selected in the regression model. Eating between meals may have had a
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36 259 bigger impact on total energy intake than eating home-cooked or ready-made meals, or eating
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39 260 vegetables. Increased time staying at home may have increased the chance of eating between meals,
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42 261 which may lead to an increase in body weight; thus, frequent checks of body weight and diet,
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45 262 especially for those eating between meals, is recommended.

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48 263 For elderly participants, an increase and decrease in home-cooked meals were also
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51 264 significantly associated with an increase and decrease in body weight, respectively. During the
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54 265 COVID-19 pandemic, the operations of supermarkets and restaurants were restricted, and the
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57 266 proportion of those that reported an increase in lunch box or ready-made meal consumption were lower
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6 267 in elderly respondents (18.2%) than adult respondents (29.9%). There is a possibility that some elderly
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9 268 participants had difficulties in buying foods at stores or using delivery services, and this resulted in a
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12 269 decrease in home-cooked meals and insufficient energy intake.
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15 270 Drinking opportunities outside the home were reduced due to the closure of bars and
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18 271 restaurants during the COVID-19 pandemic. Both an increase and decrease in alcohol intake among
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21 272 adults were significantly associated with body weight reduction in this study. Those who decreased
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24 273 alcohol intake and decreased body weight may have had a healthier lifestyle with less alcohol and less
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27 274 consumption of the side dishes and snacks that are served with alcohol. On the other hand, those who
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30 275 increased alcohol and decreased body weight may have had inadequate nutrition. For adult participants,
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33 276 the difference between participants that reported that an increase (9.1%) and decrease (7.7%) in
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36 277 alcohol intake was small. Attention should be paid to increases in alcohol intake even among people
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39 278 staying at home.
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42 279 There were several limitations to this study. A causal relationship among body weight and
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45 280 lifestyle changes was not assessed as this was a cross-sectional study. Moreover, an ordinal scale was
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48 281 used for analysis, and so quantitative assessment of physical activity or dietary intake was not
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51 282 performed.
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57 284 **CONCLUSION**
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6 285 Decrease in physical activity and increase in eating between meals were significantly associated with
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9 286 increase in body weight during the COVID-19 pandemic in Japan. Attention should be paid to
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12 287 appropriate physical activity and dietary intake, especially avoiding excessive snacking.
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18 289 **Ethics approval:** Ethical approval was obtained from the Institutional Review Board of Shiga
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21 290 University of Medical Science (R2010-029), and Ethics Committee of Kyoto Prefectural University
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24 291 (228). All participants gave informed consent to participate in the study.
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30 293 **Acknowledgments:** We deeply appreciate the Japanese Association of Public Health Center Directors
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33 294 and the Japan Medical Association for their support with NIPPON DATA2010's baseline and follow-
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36 295 up survey. The authors thank the Japanese public health centers and medical examination institutions
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39 296 listed in the Appendix of reference 4 for their support with NIPPON DATA2010's baseline survey.
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45 298 **Funding:** This study was supported by Health and Labour Sciences Research Grants of the Ministry
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48 299 of Health, Labour and Welfare, Japan (Comprehensive Research on Life-Style Related Diseases
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51 300 including Cardiovascular Diseases and Diabetes Mellitus [H22-Junkankitou-Seishuu-Sitei-017, H25-
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6 303 **Competing interests:** None declared
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12 305 **Collaborators:** *NIPPON DATA2010 Research Group*. Co-principal investigators: KM (Shiga
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27 310 University, Shimotsuke, Tochigi), Tomonori Okamura (Keio University School of Medicine, Tokyo),
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30 311 NN (National Institute of Health and Nutrition, National Institutes of Biomedical Innovation, Health
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33 312 and Nutrition, Tokyo), TO (Teikyo University School of Medicine, Tokyo), Yoshitaka Murakami
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54 319 Cardiovascular Center, Suita, Osaka), Naoyuki Takashima (Kindai University Faculty of Medicine,
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57 320 Osaka-Sayama, Osaka), Akira Fujiyoshi (Wakayama Medical University, Wakayama), Kazunori
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6 321 Kodama, Fumiyoshi Kasagi (Radiation Effects Research Foundation, Hiroshima), Yutaka Kiyohara
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12 323 Fukuoka), Toshiharu Ninomiya (Kyushu University, Fukuoka).

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18 325 **Contributors:** HT performed the statistical analysis and prepared the first draft of the manuscript.
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21 326 NO contributed to the design of the study and revised the manuscript. HA, AS, MA, NN, AH, HS,
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24 327 KM, HU, and AO contributed to the collection, assembling, and interpretation of data. All authors
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27 328 approved the final version of the manuscript.

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33 330 **Data availability statement:** Data are available upon reasonable request.

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39 332 **Supplementary Materials:**

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42 333 Table S1. Characteristics and changes in lifestyles during the COVID-19 pandemic in spring 2020 in
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45 334 Japan according to COVID-19 cases per 100,000 in address prefecture categories.

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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 (Adults, N=911)					COVID-19 cases per 100,000 in address prefecture (Elderly, N=899)				
	Q1 (lowest)	Q2	Q3	Q4 (highest)	P	Q1 (lowest)	Q2	Q3	Q4 (highest)	P
	(n=214)	(n=230)	(n=235)	(n=232)		(n=250)	(n=219)	(n=217)	(n=213)	
	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)	0.452					
50 - 69	142 (24.0)	148 (25.0)	144 (24.3)	158 (26.7)						
≥ 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)	0.143	99 (33.3)	80 (26.9)	53 (17.8)	65 (21.9)	0.003
High school	98 (25.7)	103 (27.0)	90 (23.6)	91 (23.8)		113 (26.6)	103 (24.2)	115 (27.1)	94 (22.1)	
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)	<0.001	23 (9.2)	18 (8.2)	14 (6.5)	7 (3.3)	0.027
No change	145 (67.8)	145 (63.0)	124 (52.8)	116 (50.0)		174 (69.6)	155 (70.8)	141 (65.0)	140 (65.7)	
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)	0.017	25 (10.0)	28 (12.8)	20 (9.2)	26 (12.2)	0.088
No change	169 (79.0)	165 (71.7)	167 (71.1)	164 (70.7)		214 (85.6)	189 (86.3)	193 (88.9)	176 (82.6)	
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)	0.308	14 (5.6)	11 (5.0)	19 (8.8)	19 (8.9)	0.088
No change	165 (77.1)	168 (73.0)	168 (71.5)	162 (69.8)		209 (83.6)	186 (84.9)	172 (79.3)	165 (77.5)	
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)	0.113	17 (6.8)	23 (10.5)	31 (14.3)	33 (15.5)	0.047
No change	168 (78.5)	170 (73.9)	176 (74.9)	156 (67.2)		205 (82.0)	179 (81.7)	164 (75.6)	156 (73.2)	
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)	0.130	34 (13.6)	34 (15.5)	29 (13.4)	33 (15.5)	0.897
No change	174 (81.3)	188 (81.7)	201 (85.5)	179 (77.2)		205 (82.0)	171 (78.1)	176 (81.1)	166 (77.9)	
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)	0.175	150 (60.0)	134 (61.2)	119 (54.8)	108 (50.7)	0.296
Increased	16 (7.5)	19 (8.3)	24 (10.2)	24 (10.3)		5 (2.0)	5 (2.3)	5 (2.3)	5 (2.3)	
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

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of cross-sectional studies

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	The title page 1 and the abstract page 3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 3 and 4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 5
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 5
Methods			
Study design	4	Present key elements of study design early in the paper	Page 6 to 9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 6 to 9
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	Page 6 and 9
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 7 to 9
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	N/A
Bias	9	Describe any efforts to address potential sources of bias	N/A
Study size	10	Explain how the study size was arrived at	Page 6 and 8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 7 to 9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Page 8 and 9
		(b) Describe any methods used to examine subgroups and interactions	Page 8 and 9
		(c) Explain how missing data were addressed	Page 8
		(d) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(e) Describe any sensitivity analyses	N/A

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Page 8 (Methods)
		(b) Give reasons for non-participation at each stage	Page 8 (Methods)
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 11 (Table 1)
		(b) Indicate number of participants with missing data for each variable of interest	Page 8 (Methods)
Outcome data	15*	Report numbers of outcome events or summary measures	Page 10 and 11 (Table 1)
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 12 to 16 (Table 2 and 3)
		(b) Report category boundaries when continuous variables were categorized	Page 7 to 9 (Methods)
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Page 10 and Table S1
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 17 to 20
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 21

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2022-063213.R1
Article Type:	Original research
Date Submitted by the Author:	13-Oct-2022
Complete List of Authors:	Taniguchi, Hirokazu; Kyoto Prefectural University, Division of Applied Life Sciences, Graduate School of Life and Environmental Sciences Okuda, Nagako; Kyoto Prefectural University, Division of Applied Life Sciences, Graduate School of Life and Environmental Sciences Arima, Hisatomi; Fukuoka University, Department of Preventative Medicine and Public Health Satoh, Atsushi; Fukuoka University, Department of Preventive Medicine and Public Health Abe, Makiko; Fukuoka University, Department of Preventative Medicine and Public Health Nishi, Nobuo; National Institute of Health and Nutrition, International Center for Nutrition and Information Higashiyama, Aya; Wakayama Medical University, Department of Hygiene Suzuki, Harumitsu; Wakayama Medical University, Department of Hygiene Ohkubo, Takayoshi; Teikyo University, Department of Hygiene and Public Health Kadota, Aya; Shiga University of Medical Science, NCD Epidemiologic Research Center Miura, katsuyuki; Shiga University of Medical Science, NCD Epidemiologic Research Center Ueshima, Hirotsugu; Shiga University of Medical Science, NCD Epidemiologic Research Center Okayama, Akira; Research Institute of Strategy for Prevention
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	COVID-19, PUBLIC HEALTH, EPIDEMIOLOGY

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

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27 26 **Keywords:** COVID-19, EPIDEMIOLOGY, PUBLIC HEALTH
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30 27
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33 28 **Word count:** 2944
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6 29 **Abstract**
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12 31 **Objectives** The coronavirus disease 2019 (COVID-19) pandemic has had an impact on people's
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15 32 lifestyles such as causing body weight changes. This study examined associations among lifestyle
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18 33 changes and body weight during the COVID-19 pandemic among the Japanese population.
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21 34 **Design** A cross-sectional study.
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24 35 **Setting** A nationwide survey of the general Japanese population.
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27 36 **Participants** Total participants were 2,244 men and women, of which 911 young/middle-age (30-69
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30 37 years old) and 899 older adults (70 years and older) were analyzed separately.
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33 38 **Outcome** Changes in lifestyle (physical activity, dietary habits, and alcohol intake) and body weight
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36 39 during the first wave of COVID-19 in spring 2020.
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39 40 **Results** Under the COVID-19 pandemic, 24.1% and 10.1% of Japanese respondents reported weight
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42 41 gain and reduction, respectively. Multivariable adjusted stepwise logistic regression analyses revealed
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45 42 that the young/middle-age respondents in the group that increased body weight, weight gain was
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48 43 significantly associated with decrease in physical activity (OR 4.01 [2.83-5.69]) and both increase
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51 44 (OR 5.82 [3.85-8.80]) and decrease (OR 2.73 [1.52-4.93]) in eating between meals. In the group that
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54 45 decreased body weight, body weight reduction was significantly associated with increase in physical
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57 46 activity (OR 3.66 [1.94-6.90]), decrease in eating between meals (OR 5.98 [3.11-11.48]), and both
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6 47 increase and decrease in alcohol intake in the young/middle-age. For the older adults, body weight
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9 48 gain was higher in women than in men, and significantly associated with higher quartile of regional
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12 49 COVID-19 infection, decrease in physical activity (OR 2.98 [1.98-4.49]), increase in home-cooked
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15 50 meals, and increase in eating between meals (OR 4.22 [2.55-6.99]). On the other hand, body weight
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18 51 reduction was significantly associated with decreases in physical activity (OR 2.63 [1.62-4.27]),
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21 52 home-cooked meals, and eating between meals (OR 1.95 [1.05-3.61]) in the older adults.
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24 53 **Conclusion** Changes in physical activity and eating between meals were associated with body weight
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27 54 change under the COVID-19 pandemic among Japanese.
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31 56 **Strengths and limitations of this study**

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36 57 • A nationwide survey was conducted to investigate lifestyle changes among all prefectures in
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39 58 Japan under the COVID-19 pandemic compared to before the pandemic.
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42 59 • This study examined the association of lifestyle changes with both body weight gain and loss,
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45 60 taking account of COVID-19 incidence in each region.
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48 61 • This cross-sectional study did not show a causal relationship.
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51 62 • Ordinal scale was used for analysis; thus, quantitative assessment was not performed.
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6 64 **INTRODUCTION**
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12 66 Energy balance, which is affected by lifestyle, is a key determinant factor of body weight changes.
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15 67 Physical activity increases energy expenditure and provides multiple health benefits, including body
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18 68 weight maintenance, as reported by the World Health Organization in 2020 ¹. Unhealthy dietary habits,
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21 69 such as increased snacking and decreased vegetable intake, were reported to be associated with body
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24 70 weight gain ², which is related to excess energy intake. Chronic life stress influences eating patterns
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27 71 and food preference, thereby contributing to the development of obesity ³.
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30 72 The pandemic of the coronavirus disease 2019 (COVID-19) has had an impact on people's
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33 73 lifestyles around the world. In Japan, the first state of emergency was declared by the Japanese
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36 74 government on April 7 to reduce human-to-human contact for prevention of viral infection, and was
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39 75 lifted on March 25, 2020 ⁴. Under the state of emergency, remote work was recommended, schools
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42 76 and universities were closed, and businesses, such as stores, restaurants, and fitness facilities, were
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45 77 restricted. Staying at home with less chance of physical activity and increased calorie consumption
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48 78 may cause an increase in weight gain and obesity; thus, increasing the risk of metabolic syndrome.
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51 79 Furthermore, a sedentary lifestyle is associated with undernutrition, which is a major risk factor of
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54 80 frailty ⁵ and sarcopenia ⁶, especially in older adults.
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57 81 The purpose of this study was to examine the associations of lifestyle changes and body
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6 82 weight under the spread of COVID-19 in spring 2020 among Japanese. We used the results of a
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9 83 questionnaire survey posted to the participants of the National Integrated Project for Prospective
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12 84 Observation of Non-communicable Disease and its Trends in the Aged 2010 (NIPPON DATA2010)
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15 85 in autumn 2020 ⁷.

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19 20 21 87 **METHODS**

22 23 24 88 *Participants and study design*

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30 90 We performed a cross-sectional study based on the design of NIPPON DATA2010 ⁷, a prospective
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33 91 cohort study initiated in 2010 to investigate factors associated with cardiovascular disease in Japan.

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36 92 The participants were men and women aged 20 years and older from 300 randomly selected areas
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39 93 throughout Japan who participated in the National Health and Nutrition Survey Japan (NHNSJ) ⁸ in

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42 94 2010. The baseline survey was conducted at the physical examination for the NHNSJ. Written

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45 95 informed consent was obtained from eligible participants (n = 3,244). The participants had been

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48 96 followed up for survival and cardiovascular disease events, and an additional questionnaire asking

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51 97 about lifestyle changes under the COVID-19 pandemic was sent in October 2020 to 2,244 participants

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54 98 who were alive and with known address.

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57 99 A total of 1,932 questionnaires out of 2,244 were returned (86.1% response rate), and 122

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6 100 respondents were excluded due to missing data or answering “don’t know” to any of the questions.
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9 101 The remaining 1,810 respondents were finally analyzed. They were grouped into three groups
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12 102 according to body weight change (increased, unchanged, or decreased), before and during the COVID-
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15 103 19 pandemic in spring 2020. The participants were categorized into three groups by age as of 2020:
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18 104 30-49 years, 50-69 years, and 70 years and older. All statistical analysis were performed for
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21 105 young/middle-age (30-69 years old) and older adults (70 years and older) separately, as most of the
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24 106 older adults group were retired; thus, changes in lifestyles under the COVID-19 pandemic may have
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27 107 been different.

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30 108 The study was approved by the Institutional Review Board of Shiga University of Medical
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33 109 Science (R2010-029). The Ethics Committee of Kyoto Prefectural University also approved analysis
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36 110 of the anonymized dataset (228). The patients and the public were not directly involved in the design
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45 113 *Questionnaire regarding body weight and lifestyle changes under the COVID-19 pandemic*
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51 115 In October 2020, participants were asked about changes in their lifestyle and body weight during the
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54 116 first state of emergency from April to May 2020, compared with before the COVID-19 pandemic. The
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57 117 participants were asked to write self-reported “current body weight (in kg)” and “change in body
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6 118 weight before and during the COVID-19 pandemic (April to May in 2020)". The change in body
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9 119 weight was selected from six options: "decreased ≥ 3 kg", "decreased 1-3 kg", "no change", "increased
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12 120 1-3 kg", "increased ≥ 3 kg", or "don't know".

15 121 Change in "total physical activity including exercise, sports, work, commute, housework,
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18 122 gardening, and walking." was asked. Four questions were posed about changes in dietary habits:
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21 123 "frequency of eating home-cooked meals", "frequency of eating lunch box or ready-made meals from
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24 124 supermarkets/convenience stores/takeaway shops/delivery service", "frequency or amount of eating
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27 125 between meals", and "frequency or amount of eating vegetables". Participants answered each question
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30 126 about physical activity and dietary habits from four options: "increased", "unchanged", "decreased",
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33 127 and "don't know". Change in "frequency and/or amount of alcohol consumed" was asked and the
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36 128 answering options were those used for dietary habits with the addition of the option of "non-drinker".
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42 130 *Examination regarding educational attainment and infected area*
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48 132 Educational attainment obtained from the NIPPON DATA2010 baseline survey was used as a possible
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51 133 confounding variable. Participants were grouped into three groups: graduating from elementary and
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54 134 junior high school (n = 356), high school (n = 807), or junior college/university (n = 647). Cumulative
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57 135 number of positive cases for COVID-19 per 100,000 people in each of 47 prefectures in Japan from
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6 136 the start of the disease until May 1, 2020 were calculated, and was used to explore the effects of the
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9 137 incidence of the area on changes in body weight and lifestyle⁹⁻¹¹. The prefectures were divided into
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12 138 quartile groups according to incidence, and the quartile was assigned to each participant according to
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15 139 their address. Seven prefectures, including Tokyo, were assigned to the highest infected area (Q4, 130-
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18 140 316 cases/100,000, n = 464), 11 prefectures assigned to Q3 (67.2-125.6 cases/100,000, n = 449); 13
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21 141 prefectures assigned to Q2 (34.3-66.7 cases/100,000, n = 452), and 16 prefectures assigned to Q1 (0.0-
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24 142 32.2 cases/100,000, n = 445).

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144 *Statistical analysis*

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

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6 154 P < 0.05 (two-sided) was considered significant. All statistical analyses were performed
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9 155 using IBM SPSS Statistics 26 (SPSS Inc., Chicago, IL., USA).
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157 **RESULTS**

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159 *Characteristics and changes in lifestyle according to body weight change categories*

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161 As shown in Table 1, the young/middle-age participants had a larger increase in body weight
162 (29.9%) than the older adults (18.2%). There was a no significant difference in educational status
163 among the body weight change groups in both groups. A larger proportion of participants increased
164 body weight in the areas with higher quartiles of COVID-19 cases in both young/middle-age ($P =$
165 0.032) and older adults ($P = 0.003$) groups. Participants' characteristics and answers to the
166 questionnaire according to quartiles of COVID-19 incidence are shown in Table S1. A higher
167 proportion of participants decreased physical activity in the highly infected areas for both groups.

168 All lifestyle changes during the COVID-19 pandemic asked in the questionnaire were
169 significantly different among the body weight change groups (Table 1). A larger proportion of
170 participants who answered "decreased physical activity" increased body weight in both groups. The
171 proportion of those who decreased body weight was the highest (25.3%) among those that increased

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6 172 their physical activity in the young/middle-age group; however, this was not seen in the older adults
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9 173 group. A higher proportion of body weight gain was observed among participants who reported an
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12 174 increase in home-cooked meals, lunch box and/or ready-made meals, eating between meals, and
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15 175 alcohol intake than those that reported a decrease in these dietary habits. For vegetable intake, more
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18 176 participants that reported a decrease in vegetable intake increased their body weight.
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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

Characteristics	Body weight change category (young/middle-age), n (%)				Body weight change category (older adults), n (%)			
	Increased 272 (29.9)	Unchanged 555 (60.9)	Decreased 84 (9.2)	P	Increased 164 (18.2)	Unchanged 637 (70.9)	Decreased 98 (10.9)	P
	n (%)	n (%)	n (%)		n (%)	n (%)	n (%)	
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)	
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)	

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

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6 177 *Associations among body weight change and changes in lifestyle*
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12 179 Results of multivariate logistic regression analyses showed significantly higher OR of body weight
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15 180 gain for women compared to men for both young/middle-age and older adults (Table 2). Among the
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18 181 young/middle-age group, significantly higher OR of weight gain was observed for those aged 30-49
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21 182 than those aged 50-69 years. ORs of body weight gain were higher in the higher quartiles of COVID-19
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24 183 infection compared to Q1 in both young/middle-age and older adults. Change in physical activity was
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27 184 closely related to body weight gain in both the young/middle-age and older adults. For the
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30 185 young/middle-age group, an increase and decrease in physical activity were associated with a decrease
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33 186 and increase in body weight, respectively. However, a decrease in physical activity was associated
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36 187 with both an increase and decrease in body weight in the older adults. For most of the four dietary
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39 188 habits asked in the questionnaire, both increase and decrease were significantly positively associated
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42 189 with increase and/or decrease in body weight. Especially, an increase or decrease in eating between
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45 190 meals was strongly and positively associated with body weight body weight gain or body weight
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48 191 reduction, respectively. In the young/middle-age group, an increase in alcohol intake was significantly
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51 192 positively associated with both an increase and decrease in body weight, and the decrease was
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54 193 significantly positively associated with body weight reduction in the young/middle-age group. For the
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57 194 older adults, an increase or decrease in alcohol intake was significantly positively associated with
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6 195 increase and decrease in body weight, respectively.
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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	OR	(95%CI)	P	OR	(95%CI)	P	OR	(95%CI)	P
Characteristics												
Sex												
Male	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Female	1.52	(1.11-2.07)	0.008	0.81	(0.51-1.28)	0.363	1.98	(1.38-2.86)	<0.001	1.01	(0.66-1.55)	0.953
Age (years)												
30 - 49	1.98	(1.38-2.86)	<0.001	1.01	(0.62-1.64)	0.974						
50 - 69	1.00	(Ref)		1.00	(Ref)							
Educational status												
Junior high school	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
High school	0.98	(0.53-1.80)	0.946	1.51	(0.51-4.47)	0.459	1.30	(0.87-1.94)	0.197	1.20	(0.72-1.98)	0.482
College/university	1.03	(0.57-1.88)	0.919	1.36	(0.46-4.02)	0.574	1.41	(0.86-2.31)	0.168	1.69	(0.94-3.04)	0.076
COVID-19 cases per 100,000 in address prefecture												
Quartile 1 (lowest)	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Quartile 2	1.44	(0.93-2.22)	0.100	2.38	(1.21-4.68)	0.012	1.93	(1.13-3.30)	0.016	0.80	(0.43-1.49)	0.485
Quartile 3	1.77	(1.16-2.69)	0.008	1.59	(0.77-3.27)	0.209	2.71	(1.61-4.54)	<0.001	0.98	(0.54-1.79)	0.949
Quartile 4 (highest)	1.57	(1.02-2.40)	0.039	1.54	(0.75-3.17)	0.239	2.43	(1.43-4.12)	0.001	1.40	(0.80-2.45)	0.235
Changes in lifestyles												
Physical activity												
Increased	1.00	(0.55-1.82)	0.988	4.38	(2.46-7.78)	<0.001	1.83	(0.92-3.64)	0.084	1.70	(0.76-3.80)	0.198
No change	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Decreased	4.92	(3.55-6.82)	<0.001	1.92	(1.08-3.41)	0.026	4.33	(2.97-6.32)	<0.001	2.81	(1.76-4.49)	<0.001
Home cooked meals												
Increased	1.86	(1.34-2.58)	<0.001	1.55	(0.92-2.60)	0.099	3.22	(2.01-5.16)	<0.001	1.87	(0.97-3.59)	0.060
No change	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Decreased	1.70	(0.64-4.54)	0.289	1.48	(0.32-6.94)	0.617	2.34	(0.93-5.93)	0.072	3.67	(1.44-9.36)	0.006
Lunch box and/or ready-made meals												
Increased	2.12	(1.42-3.17)	<0.001	1.21	(0.59-2.48)	0.612	2.85	(1.58-5.17)	<0.001	2.47	(1.19-5.11)	0.014
No change	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Decreased	1.76	(1.14-2.71)	0.011	2.35	(1.30-4.27)	0.005	1.80	(1.10-2.95)	0.020	1.31	(0.67-2.53)	0.427
Eating between meals												
Increased	7.05	(4.78-10.39)	<0.001	1.68	(0.78-3.61)	0.186	7.63	(4.81-12.11)	<0.001	1.64	(0.77-3.52)	0.201
No change	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Decreased	2.68	(1.53-4.69)	<0.001	6.78	(3.68-12.48)	<0.001	1.73	(0.96-3.10)	0.067	2.23	(1.23-4.05)	0.008
Vegetables												
Increased	1.77	(1.16-2.70)	0.008	2.79	(1.57-4.97)	<0.001	1.99	(1.27-3.12)	0.003	1.05	(0.56-1.97)	0.877
No change	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Decreased	2.71	(1.41-5.19)	0.003	2.75	(1.05-7.20)	0.040	4.25	(2.29-7.92)	<0.001	1.68	(0.66-4.23)	0.273
Alcohol												
No drinking	1.17	(0.85-1.61)	0.330	1.19	(0.67-2.11)	0.556	1.30	(0.88-1.91)	0.181	0.83	(0.51-1.33)	0.430
Increased	2.12	(1.26-3.56)	0.005	3.57	(1.68-7.59)	<0.001	3.02	(1.11-8.19)	0.030	1.19	(0.25-5.61)	0.823
No change	1.00	(Ref)		1.00	(Ref)		1.00	(Ref)		1.00	(Ref)	
Decreased	1.29	(0.70-2.40)	0.412	5.85	(2.91-11.76)	<0.001	1.25	(0.58-2.68)	0.569	2.76	(1.39-5.49)	0.003

CI, confidence interval; COVID-19, coronavirus disease 2019; OR, odds ratio.

The results of a multivariate logistic regression are shown.

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6 196 *Multivariable-adjusted Stepwise Logistic Regression Analyses among Body Weight and Lifestyle*

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9 197 *Changes*

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15 199 Results of multivariable-adjusted stepwise logistic regression analyses are shown in Table 3. For the

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18 200 young/middle-age group, sex was not an independent factor that affected body weight change, and

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21 201 there were no clear trends between the regional spread of COVID-19 and change in body weight. A

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24 202 decrease and increase in physical activity were significantly positively associated with body weight

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27 203 gain (OR 4.01 [2.83-5.69]) and body weight reduction (OR 3.66 [1.94-6.90]), respectively. Both an

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30 204 increase (OR 5.82 [3.85-8.80]) and decrease (OR 2.73 [1.52-4.93]) in eating between meals were

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33 205 significantly positively associated with increase in body weight. Reduced eating between meals was

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36 206 associated with body weight reduction (OR 5.98 [3.11-11.48]). Both an increase (OR 2.82 [1.27-6.30])

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39 207 and decrease (OR 4.77 [2.26-10.06]) in alcohol intake were significantly positively associated with a

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42 208 decrease in body weight.

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45 209 In the older adults, the OR of body weight gain was higher in women than that in men (OR

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48 210 1.78 [1.20-2.65]), and a higher quartile of regional COVID-19 infection was associated with higher

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51 211 OR of body weight gain, but not body weight reduction. A decrease in physical activity was

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54 212 significantly positively associated with both weight gain (OR 2.98 [1.98-4.49]) and body weight

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57 213 reduction (OR 2.63 [1.62-4.27]). An increase and decrease in home-cooked meals were significantly

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214 positively associated with body weight gain and body weight reduction, respectively. Moreover, an
215 increase and decrease in eating between meals were significantly positively associated with body
216 weight gain and body weight reduction, respectively.
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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 vs. unchanged			Decreased body weight vs. unchanged		
	OR	(95%CI)	<i>P</i>	OR	(95%CI)	<i>P</i>
Young/middle-age (aged 30-69 years)						
Characteristics						
COVID-19 cases per 100,000 in address prefecture						
Quartile 1 (lowest)	1.00	(Ref)		1.00	(Ref)	
Quartile 2	1.22	(0.75-1.98)	0.418	3.21	(1.52-6.77)	0.002
Quartile 3	1.44	(0.90-2.30)	0.132	1.71	(0.78-3.76)	0.182
Quartile 4 (highest)	1.11	(0.69-1.79)	0.674	1.28	(0.58-2.83)	0.542
Changes in lifestyles						
Physical activity						
Increased	0.93	(0.50-1.75)	0.826	3.66	(1.94-6.90)	<0.001
No change	1.00	(Ref)		1.00	(Ref)	
Decreased	4.01	(2.83-5.69)	<0.001	1.62	(0.88-2.97)	0.118
Eating between meals						
Increased	5.82	(3.85-8.80)	<0.001	1.51	(0.68-3.34)	0.313
No change	1.00	(Ref)		1.00	(Ref)	
Decreased	2.73	(1.52-4.93)	0.001	5.97	(3.11-11.48)	<0.001
Alcohol						
No drinking	0.98	(0.68-1.40)	0.900	1.02	(0.56-1.85)	0.954
Increased	1.64	(0.92-2.92)	0.095	2.82	(1.27-6.30)	0.011
No change	1.00	(Ref)		1.00	(Ref)	
Decreased	0.80	(0.40-1.60)	0.528	4.77	(2.26-10.1)	<0.001
Older adults (70 years and older)						
Characteristics						
Sex						
Male	1.00	(Ref)		1.00	(Ref)	
Female	1.78	(1.20-2.65)	0.005	0.97	(0.63-1.51)	0.903
COVID-19 cases per 100,000 in address prefecture						
Quartile 1 (lowest)	1.00	(Ref)		1.00	(Ref)	
Quartile 2	1.87	(1.05-3.31)	0.033	0.89	(0.48-1.67)	0.721
Quartile 3	2.43	(1.40-4.23)	0.002	1.01	(0.55-1.87)	0.971
Quartile 4 (highest)	2.00	(1.13-3.54)	0.017	1.34	(0.75-2.39)	0.321
Changes in lifestyles						
Physical activity						
Increased	1.46	(0.70-3.04)	0.316	1.67	(0.73-3.83)	0.224
No change	1.00	(Ref)		1.00	(Ref)	
Decreased	2.98	(1.98-4.49)	<0.001	2.63	(1.62-4.27)	<0.001
Home cooked meals						
Increased	2.02	(1.18-3.45)	0.010	1.48	(0.74-2.93)	0.267
No change	1.00	(Ref)		1.00	(Ref)	
Decreased	1.59	(0.56-4.53)	0.388	3.15	(1.19-8.32)	0.021
Eating between meals						
Increased	4.22	(2.55-6.99)	<0.001	1.03	(0.46-2.31)	0.950
No change	1.00	(Ref)		1.00	(Ref)	
Decreased	1.54	(0.83-2.82)	0.168	1.95	(1.05-3.61)	0.034

CI, confidence interval; COVID-19, coronavirus disease 2019; OR, odds ratio.

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).

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6 218 **DISCUSSION**
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12 220 This study examined the lifestyle factors that were associated with body weight changes during the
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15 221 COVID-19 pandemic in Japan in spring 2020. We found that 24.1% of respondents from the whole of
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18 222 Japan reported weight gain, and 10.1% reported weight reduction. Body weight gain was associated
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21 223 with regional COVID-19 infection in the older adults but not the young/middle-age group. The present
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24 224 study revealed that body weight gain was strongly associated with physical activity reduction and that
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27 225 an increase and decrease in eating between meals were clearly related to body weight gain and
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30 226 reduction, respectively.
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33 227 A previous study reported of Japanese patients with type 2 diabetes reported that body
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36 228 weight changes were positively associated with decreased exercise levels and snack consumption,
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39 229 resulting in increased HbA1c levels ¹². These findings suggest that the effects of lifestyle changes on
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42 230 body weight may be similar regardless of health severity during the COVID-19 pandemic. Previous
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45 231 large-scale, web-based surveys reported that mild weight gain was observed in approximately 25% of
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48 232 Japanese both in young/middle-age ¹³ and older adults ¹⁴ who lived in urban area after the start of the
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51 233 COVID-19 pandemic. Our analysis showed that over 30% of adults aged 30-49 years showed body
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54 234 weight gain, whereas the proportion was lower in the older adults aged 70 years and older
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57 235 (approximately 20%). The disagreement between these previous studies and our results may be caused
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6 236 by different methods for conducting the survey (web-based or by post) and subject area (urban or
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9 237 nationwide). Furthermore, younger people are substantially more active than older adults; thus, they
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12 238 have a higher risk of weight gain associated with staying home during the COVID-19 pandemic.

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15 239 In single regression analyses, both an increase and decrease in many dietary habits were
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18 240 significantly positively associated with body weight increase in both young/middle-age and older
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21 241 adults. In the questionnaire, we asked about changes in "frequency or amount" of foods consumed and
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24 242 did not confirm the actual amount consumed; thus, some respondents may have increased the
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27 243 frequency but decreased the amount consumed, or may have increased their consumption of some
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30 244 foods and decreased other foods, which may have led to inconsistent results.

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33 245 In stepwise regression analysis, many of the factors associated with body weight change in
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36 246 single regression analyses were not selected in the model. For young/middle-age participants, no
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39 247 characteristic factor was shown to be consistently associated with body weight change. In contrast,
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42 248 factors associated with higher risk of body weight increase in the older adults were being female and
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45 249 living in area with more COVID-19 positive cases. A much higher mortality rate of COVID-19
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48 250 infection in older adults has been reported¹⁵; thus, the older adults living in a highly infected area may
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51 251 have refrained from going out more than the young/middle-age respondents. Furthermore, women
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54 252 may have been more careful than men.

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57 253 We investigated changes in physical activity associated with body weight change both in
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6 254 young/middle-age and the older adults using stepwise regression analyses. For the young/middle-age
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9 255 group, decrease and increase of physical activity were associated with increase and decrease of body
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12 256 weight, respectively. Low levels of physical activity were an independent risk factor of obesity ¹⁶;
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15 257 thus, refraining from going out may have led to lower energy expenditure and increased body weight.
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18 258 On the other hand, some seemed to have increased physical activity and reduced body weight. It was
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21 259 reported that long working hours was associated with non-exercise habits ¹⁷ and a reduced likelihood
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24 260 of exercise ¹⁸; thus, teleworking may have allowed some in the young/middle-age group to participate
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27 261 in exercise and reduce their body weight. In older adults, a decrease in physical activity was
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30 262 significantly associated with both increase and decrease in body weight. Physical activity has a
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33 263 protective effect against the incidence of depression ¹⁹, which is a cause of unintentional weight loss
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36 264 in older adults ²⁰; therefore, it may be necessary to pay attention to risk of undernutrition in the older
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39 265 adults who reduced physical activity under the COVID-19 pandemic.

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42 266 Increase and decrease in eating between meals were significantly associated with increase
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45 267 and decrease in body weight in both the young/middle-age and older adults groups, respectively. A
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48 268 previous study in Europe reported increased snacking during lockdown and quarantine due to COVID-
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51 269 19 ²¹⁻²³, which is similar to the present study. Among the young/middle-age participants, decrease in
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54 270 eating between meals was also associated with body weight increase; thus, they may be consuming
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57 271 more calorific meals. For the young/middle-age group, the other three dietary habits were not selected
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6 272 in the regression model. Eating between meals may have had a bigger impact on total energy intake
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9 273 than eating home-cooked or ready-made meals, or eating vegetables. Increased time staying at home
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12 274 may have increased the chance of eating between meals, which may lead to an increase in body weight;
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15 275 thus, frequent checks of body weight and diet, especially for those eating between meals, is
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18 276 recommended.
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21 277 For older adults, an increase and decrease in home-cooked meals were also significantly
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24 278 associated with an increase and decrease in body weight, respectively. During the COVID-19
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27 279 pandemic, the operations of supermarkets and restaurants were restricted, and the proportion of those
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30 280 that reported an increase in lunch box or ready-made meal consumption were lower in older adults
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33 281 (18.2%) than young/middle-age respondents (29.9%). There is a possibility that some older adults had
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36 282 difficulties buying foods at stores or using delivery services, and this resulted in a decrease in home-
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39 283 cooked meals and insufficient energy intake.
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42 284 Drinking opportunities outside the home were reduced due to the closure of bars and
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45 285 restaurants during the COVID-19 pandemic. Both an increase and decrease in alcohol intake among
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48 286 the young/middle-age group were significantly associated with body weight reduction in this study.
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51 287 Those who decreased alcohol intake and decreased body weight may have had reduced opportunities
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54 288 to eat side dishes and snacks due to restaurant and bar closures. On the other hand, those who increased
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57 289 alcohol and decreased body weight may have had inadequate nutrition. For young/middle-age
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6 290 participants, the difference between participants that reported that an increase (9.1%) and decrease
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9 291 (7.7%) in alcohol intake was small. Attention should be paid to increases in alcohol intake even among
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12 292 people staying at home.

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15 293 There were several limitations to this study. A causal relationship among body weight and
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18 294 lifestyle changes was not assessed as this was a cross-sectional study. Moreover, an ordinal scale was
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21 295 used for analysis, and so quantitative assessment of physical activity or dietary intake was not
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24 296 performed. Unlike previous studies, our study did not measure metabolic and physiological conditions
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27 297 such as glycemic data ^{12, 24}, body composition ^{12, 24}, and frailty ²⁵.

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31 32 33 299 **CONCLUSION**

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36 300 Decrease in physical activity and increase in eating between meals were significantly associated with
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39 301 increase in body weight during the COVID-19 pandemic in Japan. Attention should be paid to
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42 302 appropriate physical activity and dietary intake, especially avoiding excessive snacking.

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48 304 **Ethics approval:** Ethical approval was obtained from the Institutional Review Board of Shiga
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51 305 University of Medical Science (R2010-029), and Ethics Committee of Kyoto Prefectural University
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54 306 (228). All participants gave informed consent to participate in the study.

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6 308 **Acknowledgments:** We deeply appreciate the Japanese Association of Public Health Center Directors
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8
9 309 and the Japan Medical Association for their support with NIPPON DATA2010's baseline and follow-
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12 310 up survey. The authors thank the Japanese public health centers and medical examination institutions
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15 311 listed in the Appendix of reference 4 for their support with NIPPON DATA2010's baseline survey.
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18 312

21 313 **Funding:** This study was supported by Health and Labour Sciences Research Grants of the Ministry
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23
24 314 of Health, Labour and Welfare, Japan (Comprehensive Research on Life-Style Related Diseases
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27 315 including Cardiovascular Diseases and Diabetes Mellitus [H22-Junkankitou-Seishuu-Sitei-017, H25-
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29
30 316 Junkankitou-Seishuu-Sitei-022, H30-Junkankitou-Sitei-002, 21FA2002]).
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36 318 **Competing interests:** None declared
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42 320 **Collaborators:** *NIPPON DATA2010 Research Group*. Co-principal investigators: KM (Shiga
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27 333 of Human Life Science, Osaka), Yoshihiro Miyamoto, Makoto Watanabe (National Cerebral and
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29
30 334 Cardiovascular Center, Suita, Osaka), Naoyuki Takashima (Kindai University Faculty of Medicine,
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33 335 Osaka-Sayama, Osaka), Akira Fujiyoshi (Wakayama Medical University, Wakayama), Kazunori
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36 336 Kodama, Fumiyoshi Kasagi (Radiation Effects Research Foundation, Hiroshima), Yutaka Kiyohara
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42 338 Fukuoka), Toshiharu Ninomiya (Kyushu University, Fukuoka).

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48 340 **Contributors:** HT performed the statistical analysis and prepared the first draft of the manuscript. NO
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51 341 contributed to the design of the study and revised the manuscript. HA, AS, MA, NN, AH, HS, TO,
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54 342 AK, KM, HU, and AO contributed to the collection, assembling, and interpretation of data. All authors
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57 343 approved the final version of the manuscript.
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9 345 **Data availability statement:** Data are available upon reasonable request.
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15 347 **Supplementary Materials:**
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18 348 Table S1. Characteristics and changes in lifestyles during the COVID-19 pandemic in spring 2020 in
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20 349 Japan according to COVID-19 cases per 100,000 in address prefecture categories.
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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)	Q2	Q3	Q4 (highest)	<i>P</i>	Q1 (lowest)	Q2	Q3	Q4 (highest)	<i>P</i>
	(n=214)	(n=230)	(n=235)	(n=232)		(n=250)	(n=219)	(n=217)	(n=213)	
	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)	0.452					
50 - 69	142 (24.0)	148 (25.0)	144 (24.3)	158 (26.7)						
≥ 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)	0.143	99 (33.3)	80 (26.9)	53 (17.8)	65 (21.9)	0.003
High school	98 (25.7)	103 (27.0)	90 (23.6)	91 (23.8)		113 (26.6)	103 (24.2)	115 (27.1)	94 (22.1)	
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)	<0.001	23 (9.2)	18 (8.2)	14 (6.5)	7 (3.3)	0.027
No change	145 (67.8)	145 (63.0)	124 (52.8)	116 (50.0)		174 (69.6)	155 (70.8)	141 (65.0)	140 (65.7)	
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)	0.017	25 (10.0)	28 (12.8)	20 (9.2)	26 (12.2)	0.088
No change	169 (79.0)	165 (71.7)	167 (71.1)	164 (70.7)		214 (85.6)	189 (86.3)	193 (88.9)	176 (82.6)	
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)	0.308	14 (5.6)	11 (5.0)	19 (8.8)	19 (8.9)	0.088
No change	165 (77.1)	168 (73.0)	168 (71.5)	162 (69.8)		209 (83.6)	186 (84.9)	172 (79.3)	165 (77.5)	
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)	0.113	17 (6.8)	23 (10.5)	31 (14.3)	33 (15.5)	0.047
No change	168 (78.5)	170 (73.9)	176 (74.9)	156 (67.2)		205 (82.0)	179 (81.7)	164 (75.6)	156 (73.2)	
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)	0.130	34 (13.6)	34 (15.5)	29 (13.4)	33 (15.5)	0.897
No change	174 (81.3)	188 (81.7)	201 (85.5)	179 (77.2)		205 (82.0)	171 (78.1)	176 (81.1)	166 (77.9)	
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)	0.175	150 (60.0)	134 (61.2)	119 (54.8)	108 (50.7)	0.296
Increased	16 (7.5)	19 (8.3)	24 (10.2)	24 (10.3)		5 (2.0)	5 (2.3)	5 (2.3)	5 (2.3)	
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

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of cross-sectional studies

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	The title page 1 and the abstract page 3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 3 and 4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 5
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 5 and 6
Methods			
Study design	4	Present key elements of study design early in the paper	Page 6 to 9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 6 to 9
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	Page 6 and 9
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 7 to 9
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	N/A
Bias	9	Describe any efforts to address potential sources of bias	N/A
Study size	10	Explain how the study size was arrived at	Page 6 and 8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 7 to 9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Page 8 and 10
		(b) Describe any methods used to examine subgroups and interactions	Page 7 and 10
		(c) Explain how missing data were addressed	Page 6 and 7
		(d) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(e) Describe any sensitivity analyses	N/A

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Page 6 and 7 (Methods)
		(b) Give reasons for non-participation at each stage	Page 6 and 7 (Methods)
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 12 (Table 1)
		(b) Indicate number of participants with missing data for each variable of interest	Page 6 and 7 (Methods)
Outcome data	15*	Report numbers of outcome events or summary measures	Page 10 to 12 (Table 1)
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 13 to 18 (Table 2 and 3)
		(b) Report category boundaries when continuous variables were categorized	Page 7 to 9 (Methods)
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Page 10 and Table S1
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 19
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 19 to 23
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 19
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 24

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.