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The effects of changes in eating speed on obesity

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The effects of changes in eating speed on obesity

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2
3 20 **Abstract**

4
5 21 **Objective** Few studies have examined the causal relationships between lifestyle
6
7 22 habits and obesity. With a focus on eating speed, this study aimed to analyze the
8
9 23 effects of changes in lifestyle habits on changes in obesity utilizing panel data.

10
11 24 **Methods** Patient-level panel data from 2008 to 2013 were generated using
12
13 25 commercially available insurance claims data and health checkup data. The study
14
15 26 subjects comprised Japanese men and women (n=59,717) enrolled in health insurance
16
17 27 societies who had been diagnosed with type 2 diabetes during the study period. Body
18
19 28 mass index (BMI) was measured, and obesity was defined as a BMI of 25 or more.
20
21 29 Information on lifestyle habits were obtained from the subjects' responses to
22
23 30 questions asked during health checkups. The main exposure of interest was eating
24
25 31 speed ("fast", "normal", and "slow"). Other lifestyle habits included eating dinner
26
27 32 within 2 hours of sleeping, after-dinner snacking, skipping breakfast, alcohol
28
29 33 consumption frequency, sleep adequacy, and tobacco consumption. A generalized
30
31 34 estimating equation model and fixed-effects model were used to examine the effects
32
33 35 of these habits on obesity and BMI, respectively.

34
35 36 **Results** The generalized estimating equation model showed that eating slower
36
37 37 inhibited the development of obesity. The odds ratios for slow (0.56) and normal-
38
39 38 speed eaters (0.70) indicated that these groups were less likely to be obese than fast
40
41 39 eaters ($P < 0.001$). Similarly, the fixed-effects model showed that eating slower
42
43 40 reduced BMIs. Relative to fast eaters, the coefficients for slow and normal-speed
44
45 41 eaters were -0.11 and -0.07, respectively ($P < 0.001$).

46
47 42 **Discussion** Changes in eating speed can affect changes in obesity and BMI.
48
49 43 Interventions aimed at reducing eating speed may be effective in preventing obesity
50
51 44 and lowering the associated health risks.
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56 46 **Keywords:** Body mass index, obesity, eating habits, health checkups
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3 48 **Strengths and limitations of this study**

4
5 49 1. This is the first long-term panel data analysis to verify the effects of changes in
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7 50 eating habits on obesity.

8
9 51 2. The large-scale study sample consisted of approximately 60,000 young to middle-
10
11 52 aged subjects.

12
13 53 3. The analysis also examined alcohol consumption, sleep adequacy, and tobacco
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15 54 consumption.

16
17 55 4. Lifestyle habits were self-assessed and may therefore be vulnerable to reporting
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19 56 bias.

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21 57 5. The sample comprised relatively health-conscious individuals who voluntarily
22
23 58 participated in health checkups, and the findings may therefore have limited
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25 59 applicability to less health-conscious people.
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32
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34
35 64 010)
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40 66 **Competing Interests Statement:**

41 67 No potential conflicts of interest relevant to this article were reported.
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47 70 **Author Contributions:**

48 71 YH contributed to data analysis and interpretation, and drafting of the manuscript. HF
49
50 72 contributed to the study concept, design, and interpretation, and drafting of the
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52 73 manuscript.
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74 Introduction

75 Excess body weight and obesity can lead to an increased risk of developing
76 noncommunicable diseases such as cardiovascular disease, diabetes, and various
77 forms of cancer.¹⁻⁴ Studies have reported that the regulation of body weight can be
78 effective in lowering these health risks.¹⁻⁴ However, a 10-year longitudinal study of
79 Japanese men aged 40 to 69 years found that the proportion of overweight and obese
80 individuals had increased over the study period.⁵ In addition, the Japanese
81 government's *Annual Health, Labour and Welfare Report 2014* noted that the
82 prevalence of obesity continues to rise, with a substantially higher prevalence among
83 men in 2012 than in 1982.⁶ The report also revealed that obesity prevalence exceeded
84 30% in men in their 40s and 50s. These figures suggest that current obesity
85 prevention efforts in Japan may be inadequate.

86 The fundamental cause of excess weight gain is the failure to ensure a balance
87 between energy intake and energy expenditure.¹ However, recent studies have
88 reported that excess weight gain and metabolic syndrome are affected not only by
89 energy intake, but are also influenced by other factors such as eating speed, eating
90 frequency, and other lifestyle habits.⁷⁻¹⁰ In addition to emphasizing the importance of
91 balancing energy intake and expenditure, these other factors represent possible targets
92 for obesity prevention measures.

93 In response to the rising prevalence of obesity, Japan's Ministry of Health,
94 Labour and Welfare introduced a nationwide health screening program (Standard
95 Health Checkup and Counseling Guidance Program) to detect risk factors for obesity
96 and metabolic syndrome.^{11,12} Under this program, insurers conduct "specific health
97 checkups" aimed at insurance enrollees aged 40 years or older. However, participation
98 in these checkups is not mandatory.

99 Although many studies have addressed the associations between lifestyle habits
100 and obesity, few have examined the causal effects of changes in lifestyle habits on
101 obesity. The main objective of this study was to utilize panel data to analyze the

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3 102 effects of changes in eating speed and other lifestyle habits on obesity.
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6
7 104 **Methods**

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9 105 **Data source**

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11 106 This study used a commercial database obtained from the Japan Medical Data Center
12
13 107 (JMDC), a for-profit organization that collects, curates, and distributes health-related
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15 108 data. The database comprised insurance claims data and health checkup data for
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17 109 insurance enrollees and their dependents that were collected through JMDC's
18
19 110 contracts with several health insurance societies. The claims data included
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21 111 information on the dates of consultations and treatments, sex, age, diagnoses, specific
22
23 112 treatments, and healthcare expenditure. The health checkup data included the dates of
24
25 113 checkups, body mass index (BMI), blood pressure, and the results of blood chemical
26
27 114 analysis, liver function test, blood glucose test, and urinalysis. The health checkup
28
29 115 data also included the subjects' responses to several questions regarding lifestyle
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31 116 factors, such as eating habits, alcohol consumption, tobacco use, and sleeping
32
33 117 habits.¹² The claims data and health checkup data were linked at the individual
34
35 118 subject level for analysis.
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39 120 **Study design**

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41 121 We first identified subjects with at least one recorded diagnosis of type 2 diabetes in
42
43 122 their claims data from January 2005 to June 2013. Both the claims data and health
44
45 123 checkup data from this study period were used in the analysis. From the claims data,
46
47 124 we obtained information on subject sex, age, and the starting date of anti-diabetic
48
49 125 medication. The claims data were linked with the health checkup data at the patient-
50
51 126 month level to generate panel data. We excluded subjects with missing data for BMI
52
53 127 and lifestyle habits. The results from each subject's first specific health checkup
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55 128 during the study period were used as the baseline values.
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130 Outcomes

131 The primary outcome of this study was obesity status. According to the World Health
132 Organization's criteria, a BMI of 25 or more indicates that a person is overweight,
133 and a BMI of 30 or more indicates obesity. However, it has been proposed that these
134 BMI cut-off points should be lower for Asian populations.¹³ The Japan Society for the
135 Study of Obesity has recommended that obesity be defined by a BMI of 25 or more
136 for the Japanese population.¹⁴ In accordance with this recommendation, our study
137 uses a BMI cut-off point of 25 to identify obese individuals. The secondary outcome
138 of this study was BMI, which was analyzed as a continuous variable.

140 Exposure variables

141 The exposure variables consisted of the 7 question items regarding lifestyle habits.
142 The main exposure of interest was eating speed. The other items were eating dinner
143 within 2 hours before sleeping for 3 times or more per week, snacking after dinner for
144 3 times or more per week, skipping breakfast 3 times or more per week, alcohol
145 consumption frequency, sleep adequacy, and habitual smoking. These variables were
146 analyzed as categorical variables based on the response options. Eating speed was
147 analyzed as 3 categories ("fast", "normal", and "slow"). Eating dinner within 2 hours
148 before sleeping for 3 times or more per week, snacking after dinner for 3 times or
149 more per week, skipping breakfast 3 times or more per week, adequate sleep, and
150 habitual smoking were analyzed as 2 categories ("yes" and "no"). Alcohol
151 consumption frequency was analyzed as 3 categories ("every day", "occasionally",
152 and "rarely or never").

154 Covariates

155 The covariates were selected from factors thought to influence lifestyle habits and
156 weight management. These included the use of anti-diabetic medication (as an
157 indicator of diabetes that requires pharmacologic treatment), age, as well as obesity

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3 158 status and BMI in the previous checkup. The use or non-use of anti-diabetic
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5 159 medication was determined based on whether the patient had been administered anti-
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7 160 diabetic medication at the time of each health checkup. This variable was analyzed as
8
9 161 2 categories (“yes” and “no”). In addition to human insulin preparations and insulin
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11 162 analogs, anti-diabetic medications also included sulfonylureas, biguanide derivatives,
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13 163 glitazones, α -glucosidase inhibitors, glinides, DPP-4 inhibitors, and GLP-1 receptor
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15 164 agonists. Age and BMI in the previous checkup were analyzed as continuous variables.
16
17 165 Obesity status in the previous checkup was analyzed as 2 categories (“yes” for BMI
18
19 166 ≥ 25 and “no” for BMI < 25).
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22 23 168 **Statistical analysis**

24
25 169 The subject baseline characteristics of sex, age, BMI, obesity status, and lifestyle
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27 170 habits were compared among the 3 eating speed categories using the χ^2 test or one-
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29 171 way analysis of variance. Patient-level panel data were generated using repeated
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31 172 estimates from multiple health checkups. We constructed a generalized estimating
32
33 173 equation model to elucidate the effects of changes in eating speed on obesity. The
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35 174 dependent variable was obesity status. The exposure variables were the 7 lifestyle
36
37 175 habit items, and the covariates were the use of anti-diabetic medication, age, and
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39 176 obesity status in the previous checkup.

40
41 177 In order to estimate the influence of changes in eating speed on BMI, we
42
43 178 utilized a fixed-effects model where the dependent variable was BMI. The exposure
44
45 179 variables were the 7 lifestyle habit items, and the covariates were the use of anti-
46
47 180 diabetic medication, age, and BMI in the previous checkup. The Hausman test was
48
49 181 employed for model selection.

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51 182 All statistical analyses were conducted using Stata 13.1 (Stata Corp., College
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53 183 Station, TX, USA). Statistical significance was set at $P < 0.05$.

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185 Results

186 We identified 92,363 individuals from 303,361 person-months who had been
187 diagnosed with type 2 diabetes and had health checkup data for the period between
188 January 2005 and June 2013. After excluding cases with missing data in BMI and the
189 lifestyle habit items, the sample for analysis comprised 59,717 individuals from
190 129,978 person-months. The claims data and health checkup data that could be linked
191 for analysis covered the period from February 2008 to June 2013.

192 The distribution of baseline characteristics according to eating speed is
193 presented in Table 1. The slow-eating group had a significantly higher proportion of
194 women (44.4%), lower mean BMI (22.3 ± 4.0), lower proportion of obese individuals
195 (21.5%), lower alcohol consumption frequency (every day: 22.8%; occasionally:
196 27.5%; rarely or never: 49.7%), and lower proportion of habitual smokers (27.3%)
197 when compared with the other 2 groups (all: $P < 0.001$). In contrast, the fast-eating
198 group had a significantly lower proportion of women (27.3%, $P < 0.001$), but a
199 significantly higher mean BMI (25.0 ± 4.4 , $P < 0.001$) and higher proportion of obese
200 individuals (44.8%, $P < 0.001$).

201 Table 2 shows the estimated odds ratios (ORs) of the various determinants of
202 obesity derived from the generalized estimating equation model. All eating habit
203 items, alcohol consumption frequency, sleep adequacy, and obesity status in the
204 previous checkup were significantly associated with obesity. When compared with the
205 fast-eating group, the slower eating speeds were significantly associated with reduced
206 ORs for obesity (normal: 0.70; slow: 0.56; $P < 0.001$). This indicated that slower
207 eating speeds may lead to the alleviation of obesity. The results also showed that
208 reduced alcohol consumption frequency was significantly associated with higher ORs
209 for obesity (occasionally: 1.13, $P < 0.001$; rarely or never: 1.09, $P = 0.002$). In
210 addition, inadequate sleep was significantly associated with a higher OR for obesity
211 (1.05, $P = 0.023$). Habitual smoking and use of anti-diabetic medication were not
212 significantly associated with the outcome.

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3 213 The estimated coefficients of the various determinants of changes in BMI are
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5 214 presented in Table 3. Eating speed (normal: $P < 0.001$; slow: $P < 0.001$), eating
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7 215 dinner within 2 hours before sleeping for 3 times or more per week ($P < 0.001$),
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9 216 snacking after dinner for 3 times or more per week ($P < 0.001$), BMI in the previous
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11 217 checkup ($P < 0.001$), alcohol consumption frequency (occasionally: $P < 0.001$; rarely
12
13 218 or never: $P = 0.002$), sleep adequacy ($P < 0.001$), and age ($P = 0.008$) were
14
15 219 significantly associated with changes in BMI. With the exception of age and BMI in
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17 220 the previous checkup, the coefficients of all the other factors were negative. This
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19 221 indicated that eating slower, not eating dinner within 2 hours before sleeping, not
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21 222 snacking after dinner, drinking infrequently, and not obtaining adequate sleep were
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23 223 associated with reductions in BMI. Skipping breakfast 3 times or more per week,
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25 224 habitual smoking, and the use of anti-diabetic medication were not significantly
26
27 225 associated with BMI.

226

227 **Discussion**

228 This study analyzed Japanese men and women who had undergone specific health
229 checkups regardless of obesity status. Possible lifestyle-related determinants of
230 obesity were identified using questionnaire items from the Standard Health Checkup
231 and Counseling Guidance Program.¹² We examined 6-year panel data to determine
232 how changes in eating speed and other lifestyle habits affect obesity and BMI. The
233 main results indicated that decreases in eating speeds can lead to reductions in
234 obesity and BMI after controlling for the covariates. In addition, the study found that
235 the cessation of eating after dinner or within 2 hours before sleeping would also have
236 a similar effect on reducing excess body weight.

237 The use of panel data increases the accuracy of estimates with substantial
238 increases in the variable of interest when compared with conventional cross-sectional
239 and time series data.¹⁵ Panel data also enable adjustments of the unobservable
240 differences between study subpopulations, thereby facilitating analyses of the effects

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3 241 of behavioral changes in subjects.

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5 242 The major finding of this study is that changes in eating speed affect obesity
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7 243 and BMI. The control of eating speed may therefore be a possible means of regulating
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9 244 body weight and preventing obesity, which in turn reduces the risk of developing
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11 245 noncommunicable diseases. Eating quickly is associated with impaired glucose
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13 246 tolerance and insulin resistance,^{16,17} and is a known risk factor for diabetes through
14
15 247 increases in body weight.¹⁸ Other studies have also reported associations between
16
17 248 eating quickly and increased BMI, indicating that eating speed is a contributing factor
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19 249 for obesity.^{7,8,19-24} A possible reason for this association is that fast eaters may
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21 250 continue to eat until they feel full despite having already consumed an adequate
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23 251 amount of calories, and the combined effect of eating quickly and overeating may
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25 252 contribute to weight gain.²⁵ In contrast, eating slowly may help to increase feelings of
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27 253 satiety before an excessive amount of food is ingested.²⁶⁻²⁸ A prospective study of
28
29 254 schoolgirls found that the reduction of eating speed was able to suppress weight gain
30
31 255 and prevent obesity.²⁹ The findings of these studies are consistent with those of our
32
33 256 analysis.

34
35 257 Our results also indicated that frequently eating dinner within 2 hours before
36
37 258 sleeping, snacking after dinner, and skipping breakfast contribute to the development
38
39 259 of obesity. Previous studies have identified eating after dinner and within 2 hours
40
41 260 before sleeping as risk factors of metabolic syndrome.⁷ This supports our findings
42
43 261 that the cessation of these habits can help to reduce obesity and BMI. Skipping
44
45 262 breakfast has also been shown to be associated with excess weight and obesity, and is
46
47 263 a risk factor of metabolic syndrome.^{7,9,30} Our generalized estimating equation model
48
49 264 revealed that consistently eating breakfast can reduce obesity, which also
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51 265 corroborates the findings of previous studies. However, our fixed-effects model
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53 266 showed that consistently eating breakfast did not affect changes in BMI. It has been
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55 267 reported that skipping breakfast over a long-period is associated with high BMI and
56
57 268 elevated cardiometabolic risks.³¹ Consistently eating breakfast may therefore help to

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3 269 control obesity and BMI.

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5 270 Daily alcohol consumption has been reported to be positively associated with
6
7 271 obesity, and is another risk factor of metabolic syndrome.^{7,32} However, our findings
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9 272 indicated that alcohol consumption frequency was not significantly associated with
10
11 273 obesity. Previous studies have reported that the frequency of alcohol consumption
12
13 274 (given the same quantities of alcohol) was inversely associated with obesity.^{33,34} It is
14
15 275 possible that the subjects in this study who drank with higher frequency were
16
17 276 consuming moderate quantities of alcohol, whereas the subjects who drank
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19 277 infrequently consumed larger quantities during each session.

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21 278 Studies have also found associations between short sleep durations and BMI
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23 279 increases, and that poor-quality sleep is associated with metabolic syndrome.³⁵⁻³⁷ Our
24
25 280 analysis produced contradictory results in that a change from adequate sleep to
26
27 281 inadequate sleep would reduce BMI but increase obesity progression. A recent study
28
29 282 has shown that unstable sleep patterns may increase the quantity of food intake,³⁸ and
30
31 283 our findings therefore require further investigation. The lack of association between
32
33 284 habitual smoking and BMI or metabolic syndrome has been reported in previous
34
35 285 studies,^{7,39} which corroborates our findings.

36
37 286 This study has several limitations that should be considered. First, this study
38
39 287 utilized health checkup data from health insurance societies. As a result, the data may
40
41 288 not have included a large proportion of the insurance enrollees' dependents. In
42
43 289 particular, there was a relatively small proportion of older adults in our study
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45 290 population. The results may therefore lack generalizability to other subpopulations.
46
47 291 Second, eating speed and the other lifestyle habits were self-assessed, and may
48
49 292 therefore be vulnerable to reporting bias. However, while the differences in
50
51 293 perceptions of eating and sleeping habits in standardized questionnaires have been
52
53 294 described,⁴¹ Sasaki *et al.* reported that there was no difference between the eating
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55 295 speeds assessed by study subjects or by friends of the subjects.²³ In addition, our
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57 296 findings are consistent with those of a previous study that used objective measures of
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3 297 eating speed and found that slower eating speeds were associated with greater weight
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5 298 loss.²⁸ Thirdly, we did not include an analysis of physical exercise. Nevertheless, a
6
7 299 previous analysis has reported that eating speed was associated with obesity
8
9 300 regardless of the level of physical activity.²⁴ In addition, other studies have reported
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11 301 similar associations between eating speed and BMI given similar overall food intake,
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13 302 which corroborates our findings.^{22,23} Finally, the sample comprised relatively health-
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15 303 conscious individuals who voluntarily participated in health checkups. The findings
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17 304 may therefore have limited applicability to less health-conscious people.

18
19 305 Many studies have shown that eating habits are associated with BMI and weight
20
21 306 gain.^{7,8,16-29} However, this study utilized panel data to show that changes in eating
22
23 307 habits have a causal relationship with obesity and BMI. These findings indicate that
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25 308 weight loss can be supported through the reduction of eating speed, the cessation of
26
27 309 eating dinner within 2 hours before sleeping, the cessation of snacking after dinner,
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29 310 and consistently having breakfast.

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31 311

32 **Conclusions**

33
34 313 Changes in eating habits can affect obesity and BMI. Interventions aimed at altering
35
36 314 eating habits, such as education initiatives and programs to reduce eating speed, may
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38 315 be useful in preventing obesity and reducing the risk of noncommunicable diseases.

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426 **Table 1. Distribution of baseline characteristics according to eating speed**

	Eating Speed			P
	Fast (n = 22,062)	Normal (n = 33,460)	Slow (n = 4,191)	
Number of checkups	4.2 [1.5]	4.2 [1.6]	4.4 [1.6]	<0.001 ^b
Women	6,023 (27.3%)	12,213 (36.5%)	1,861 (44.4%)	<0.001 ^a
Age	46.6 [10.4]	48.1 [10.6]	46.5 [11.7]	<0.001 ^b
Use of anti-diabetic medications	13,648 (61.8%)	20,074 (60%)	2,525 (60.2%)	<0.001 ^a
BMI, kg/m ²	25 [4.4]	23.4 [4.0]	22.3 [4.0]	<0.001 ^b
Obese (BMI ≥25)	9,884 (44.8%)	9,886 (29.6%)	901 (21.5%)	<0.001 ^a
Eating dinner within 2 hours before sleeping ≥3 times per week	9,545 (43.3%)	11,161 (33.4%)	1,541 (36.8%)	<0.001 ^a
Snacking after dinner ≥3 times per week	4,247 (19.2%)	4,851 (14.5%)	809 (19.3%)	<0.001 ^a
Skipping breakfast ≥3 times per week	4,599 (20.8%)	5,542 (16.6%)	794 (18.9%)	<0.001 ^a
Alcohol consumption				
Every day	5,695 (25.8%)	8,810 (26.3%)	955 (22.8%)	<0.001 ^a
Occasionally	7,233 (32.8%)	10,398 (31.1%)	1,152 (27.5%)	<0.001 ^a
Rarely or never	9,142 (41.4%)	14,247 (42.6%)	2,085 (49.7%)	<0.001 ^a
Obtain adequate sleep	10,834 (49.1%)	18,437 (55.1%)	2,238 (53.4%)	<0.001 ^a
Habitual smoker	7,140 (32.4%)	10,239 (30.6%)	1,146 (27.3%)	<0.001 ^a

427 ^a χ^2 test428 ^b One-way analysis of variance429 Values for number of checkups, age, and BMI are presented as mean [standard deviation]. All
430 other values are presented as number of subjects (proportion of each eating-speed group).

431 Abbreviation: BMI, body mass index.

432 **Table 2. Estimated odds ratios of the determinants of obesity derived from the**
 433 **generalized estimating equation model**

	Odds Ratio	95% Confidence Intervals	P
Eating speed			
Fast	REF		
Normal	0.70	0.67 - 0.73	<0.001
Slow	0.56	0.52 - 0.61	<0.001
Eating dinner within 2 hours before sleeping ≥ 3 times per week			
Yes	REF		
No	0.85	0.81 - 0.89	<0.001
Snacking after dinner ≥ 3 times per week			
Yes	REF		
No	0.89	0.82 - 0.92	<0.001
Skipping breakfast ≥ 3 times per week			
Yes	REF		
No	0.92	0.87 - 0.97	0.003
Alcohol consumption			
Every day	REF		
Occasionally	1.13	1.07 - 1.20	<0.001
Rarely or never	1.09	1.03 - 1.15	0.002
Obtain adequate sleep			
Yes	REF		
No	1.05	1.01 - 1.10	0.023
Habitual smoker			
Yes	REF		
No	1.02	0.98 - 1.07	0.363
Use of anti-diabetic medication			
No	REF		
Yes	1.04	0.997 - 1.087	0.069
Age	0.997	0.995 - 0.999	0.008
Obesity status in the previous checkup			
Not obese	REF		
Obese	172.36	163.35 - 181.87	<0.001

434

435 **Table 3. Estimated coefficients of the determinants of changes in BMI derived**
 436 **from the fixed-effects model**

	Coefficient	95% Confidence Intervals	P
Eating speed			
Fast	REF		
Normal	-0.07	-0.10, -0.05	<0.001
Slow	-0.11	-0.15, -0.06	<0.001
Eating dinner within 2 hours before sleeping ≥ 3 times per week			
Yes	REF		
No	-0.06	-0.08, -0.04	<0.001
Snacking after dinner ≥ 3 times per week			
Yes	REF		
No	-0.08	-0.11, -0.06	<0.001
Skipping breakfast ≥ 3 times per week			
Yes	REF		
No	0.00	-0.03, 0.04	0.818
Alcohol consumption			
Every day	REF		
Occasionally	-0.10	-0.13, -0.06	<0.001
Rarely or never	-0.17	-0.22, -0.13	0.002
Obtain adequate sleep			
Yes	REF		
No	-0.03	-0.05, -0.01	0.001
Habitual smoker			
Yes	REF		
No	0.23	0.20, 0.27	0.363
Use of anti-diabetic medication			
No	REF		
Yes	-0.12	-0.14, -0.10	0.069
Age	0.08	0.07, 0.10	0.008
BMI in the previous checkup	0.09	0.07, 0.10	<0.001

437 Abbreviation: BMI, body mass index.

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The effects of changes in eating speed on obesity: a secondary analysis of longitudinal health checkup data

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22 Abstract

23 **Objective** Few studies have examined the causal relationships between lifestyle
24 habits and obesity. With a focus on eating speed, this study aimed to analyze the
25 effects of changes in lifestyle habits on changes in obesity utilizing panel data.

26 **Methods** Patient-level panel data from 2008 to 2013 were generated using
27 commercially available insurance claims data and health checkup data. The study
28 subjects comprised Japanese men and women (n=59,717) enrolled in health insurance
29 societies who had been diagnosed with type 2 diabetes during the study period. Body
30 mass index (BMI) was measured, and obesity was defined as a BMI of 25 or more.
31 Information on lifestyle habits were obtained from the subjects' responses to
32 questions asked during health checkups. The main exposure of interest was eating
33 speed ("fast", "normal", and "slow"). Other lifestyle habits included eating dinner
34 within 2 hours of sleeping, after-dinner snacking, skipping breakfast, alcohol
35 consumption frequency, sleep adequacy, and tobacco consumption. A generalized
36 estimating equation model and fixed-effects model were used to examine the effects
37 of these habits on obesity and BMI, respectively.

38 **Results** The generalized estimating equation model showed that eating slower
39 inhibited the development of obesity. The odds ratios for slow (0.58) and normal-
40 speed eaters (0.71) indicated that these groups were less likely to be obese than fast
41 eaters ($P < 0.001$). Similarly, the fixed-effects model showed that eating slower
42 reduced BMIs. Relative to fast eaters, the coefficients for slow and normal-speed
43 eaters were -0.11 and -0.07, respectively ($P < 0.001$).

44 **Discussion** Changes in eating speed can affect changes in obesity and BMI.
45 Interventions aimed at reducing eating speed may be effective in preventing obesity
46 and lowering the associated health risks.

47
48 **Keywords:** Body mass index, obesity, eating habits, health checkups

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50 **Strengths and limitations of this study**

- 51 1. This is the first panel data analysis to verify the effects of changes in eating
52 habits on obesity.
- 53 2. Long-term large-scale longitudinal data were used.
- 54 3. Lifestyle habits were self-assessed and may be vulnerable to reporting bias.
- 55 4. The sample comprised relatively health-conscious individuals who voluntarily
56 participated in health checkups, and the findings may therefore have limited
57 applicability to less health-conscious people.

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59 Introduction

60 Excess body weight and obesity can lead to an increased risk of developing
61 noncommunicable diseases such as diabetes, cardiovascular disease, and various
62 forms of cancer.¹⁻⁴ Studies have reported that the regulation of body weight can be
63 effective in lowering these health risks.¹⁻⁴ However, a 10-year longitudinal study of
64 Japanese men aged 40 to 69 years found that the proportion of overweight and obese
65 individuals had increased over the study period.⁵ In addition, the Japanese
66 government's *Annual Health, Labour and Welfare Report 2014* noted that the
67 prevalence of obesity continues to rise, with a substantially higher prevalence among
68 men in 2012 than in 1982.⁶ The report also revealed that obesity prevalence exceeded
69 30% in men in their 40s and 50s. These figures suggest that current obesity
70 prevention efforts in Japan may be inadequate.

71 The fundamental cause of excess weight gain is the failure to ensure a balance
72 between energy intake and energy expenditure.¹ However, recent studies have
73 reported that excess weight gain and metabolic syndrome are affected not only by
74 energy intake, but are also influenced by other factors such as eating speed, eating
75 frequency, and other lifestyle habits.⁷⁻¹⁰ In addition to emphasizing the importance of
76 balancing energy intake and expenditure, these other factors represent possible targets
77 for obesity prevention measures.

78 In response to the rising prevalence of obesity, Japan's Ministry of Health,
79 Labour and Welfare introduced a nationwide health screening program (Standard
80 Health Checkup and Counseling Guidance Program) to detect risk factors for obesity
81 and metabolic syndrome.^{11,12} Under this program, insurers conduct "specific health
82 checkups" aimed at insurance enrollees aged 40 years or older. However, participation
83 in these checkups is not mandatory.

84 Although many studies have addressed the associations between lifestyle habits
85 and obesity, few have examined the causal effects of changes in lifestyle habits on
86 obesity. In addition, studies from Japan have shown that the number of persons with

1
2
3 87 type 2 diabetes has increased with increasing BMI¹³, and that BMI is an independent
4
5 88 risk factor for this condition¹⁴. This study focuses on persons with type 2 diabetes as
6
7 89 they are likely to benefit directly from health improvements arising from the
8
9 90 alleviation of obesity. The main objective of this study was to utilize panel data to
10
11 91 analyze the effects of changes in eating speed and other lifestyle habits on obesity.
12
13 92 For this analysis, we hypothesized that slower eating speeds would reduce obesity.
14
15 93

94 **Methods**

95 **Data source**

96 This study used a commercial database obtained from the Japan Medical Data Center
97 (JMDC), a for-profit organization that collects, curates, and distributes health-related
98 data. The database comprised insurance claims data and health checkup data for
99 insurance enrollees and their dependents that were collected through JMDC's
100 contracts with several health insurance societies in Japan. The claims data included
101 information on the dates of consultations and treatments, sex, age, diagnoses, specific
102 treatments, and healthcare expenditure. The health checkup data included the dates of
103 checkups, body mass index (BMI), waist circumference, blood pressure, and the
104 results of blood chemical analysis, liver function test, blood glucose test, and
105 urinalysis. The health checkup data also included the subjects' responses to several
106 questions regarding lifestyle factors, such as eating habits, alcohol consumption,
107 tobacco use, and sleeping habits.¹² The claims data and health checkup data were
108 linked at the individual subject level for analysis. Approval for this study was
109 obtained from the ethics committee of the JMDC.

111 **Study design**

112 We first identified subjects with at least one recorded diagnosis of type 2 diabetes in
113 their claims data from January 2005 to June 2013 using the corresponding
114 International Classification of Diseases, 10th revision codes (E10–E14). Both the

1
2
3 115 claims data and health checkup data from this study period were used in the analysis.
4
5 116 From the claims data, we obtained information on subject sex, age, and the starting
6
7 117 date of anti-diabetic medication. The claims data were linked with the health checkup
8
9 118 data at the patient-month level to generate panel data. We excluded subjects with
10
11 119 missing data for BMI and lifestyle habits. The results from each subject's first
12
13 120 specific health checkup during the study period were used as the baseline values.
14
15 121

122 **Outcomes**

123 The primary outcome of this study was obesity status. According to the World Health
124
125 Organization's criteria, a BMI of 25 or more indicates that a person is overweight,
126
127 and a BMI of 30 or more indicates obesity. However, it has been proposed that these
128
129 BMI cut-off points should be lower for Asian populations.¹⁵ The Japan Society for the
130
131 Study of Obesity has recommended that obesity be defined by a BMI of 25 or more
132
133 for the Japanese population.¹⁶ In accordance with this recommendation, our study
134
135 uses a BMI cut-off point of 25 to identify obese individuals. The secondary outcome
136
137 of this study was BMI, which was analyzed as a continuous variable.
138
139

140 **Exposure variables**

141 The exposure variables consisted of the 7 question items regarding lifestyle habits.
142
143 The main exposure of interest was eating speed. The other items were eating dinner
144
145 within 2 hours before sleeping for 3 times or more per week, snacking after dinner for
146
147 3 times or more per week, skipping breakfast 3 times or more per week, alcohol
148
149 consumption frequency, sleep adequacy, and habitual smoking. These variables were
150
151 analyzed as categorical variables based on the response options. Eating speed was
152
153 analyzed as 3 categories ("fast", "normal", and "slow"). Eating dinner within 2 hours
154
155 before sleeping for 3 times or more per week, snacking after dinner for 3 times or
156
157 more per week, skipping breakfast 3 times or more per week, adequate sleep, and
158
159 habitual smoking were analyzed as 2 categories ("yes" and "no"). Alcohol
160

1
2
3 143 consumption frequency was analyzed as 3 categories (“every day”, “occasionally”,
4 144 and “rarely or never”).

5
6 145

7 8 146 **Covariates**

9
10 147 The covariates were selected from factors thought to influence lifestyle habits and
11
12 148 weight management. These included the use of anti-diabetic medication (as an
13
14 149 indicator of diabetes that requires pharmacologic treatment), age, as well as obesity
15
16 150 status and BMI in the previous checkup. The use or non-use of anti-diabetic
17
18 151 medication was determined based on whether the patient had been administered anti-
19
20 152 diabetic medication at the time of each health checkup. This variable was analyzed as
21
22 153 2 categories (“yes” and “no”). In addition to human insulin preparations and insulin
23
24 154 analogs, anti-diabetic medications also included sulfonylureas, biguanide derivatives,
25
26 155 glitazones, α -glucosidase inhibitors, glinides, DPP-4 inhibitors, and GLP-1 receptor
27
28 156 agonists. Age and BMI in the previous checkup were analyzed as continuous variables.
29
30 157 Obesity status in the previous checkup was analyzed as 2 categories (“yes” for BMI
31
32 158 ≥ 25 and “no” for BMI < 25).

33
34 159

35 36 160 **Statistical analysis**

37
38 161 The subject baseline characteristics of sex, age, BMI, obesity status, and lifestyle
39
40 162 habits were compared among the 3 eating speed categories using the χ^2 test or one-
41
42 163 way analysis of variance. Patient-level panel data were generated using repeated
43
44 164 estimates from multiple health checkups. This study used longitudinal data from
45
46 165 annual health checkups collected over approximately 6 years. The application of
47
48 166 panel data enables the estimation of changes in the dependent variables that result
49
50 167 from changes in eating speed (e.g., fast to fast, fast to normal, fast to slow, and so on)
51
52 168 in individual subjects.

53
54 169 We first constructed a generalized estimating equation model to elucidate the
55
56 170 effects of changes in eating speed on obesity. The exposure variables were the 7

1
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3 171 lifestyle habit items, and the covariates were the use of anti-diabetic medication, age,
4
5 172 sex, and obesity status in the previous checkup.

6
7 173 In order to estimate the influence of changes in eating speed on BMI, we
8
9 174 utilized a fixed-effects model where the dependent variable was BMI. The exposure
10
11 175 variables were the 7 lifestyle habit items, and the covariates were the use of anti-
12
13 176 diabetic medication, age, and BMI in the previous checkup. Sex and other covariates
14
15 177 that remained unchanged throughout the observation period were adjusted as fixed
16
17 178 effects. The Hausman test was employed for model selection; the *P*-value was below
18
19 179 0.001, which confirmed that the use of the fixed-effects model was appropriate.

20
21 180 All statistical analyses were conducted using Stata 13.1 (Stata Corp., College
22
23 181 Station, TX, USA). Statistical significance was set at $P < 0.05$.

24
25 182

26 27 183 **Results**

28
29 184 We identified 92,363 individuals from 303,361 person-months who had been
30
31 185 diagnosed with type 2 diabetes and had health checkup data for the period between
32
33 186 January 2005 and June 2013. After excluding cases with missing data in BMI and the
34
35 187 lifestyle habit items, the sample for analysis comprised 59,717 individuals from
36
37 188 129,978 person-months. The claims data and health checkup data that could be linked
38
39 189 for analysis covered the period from February 2008 to June 2013.

40
41 190 The distribution of baseline characteristics according to eating speed is
42
43 191 presented in Table 1. The slow-eating group had a significantly higher proportion of
44
45 192 women (44.4%), lower mean BMI (22.3 ± 4.0), lower proportion of obese individuals
46
47 193 (21.5%), lower alcohol consumption frequency (every day: 22.8%; occasionally:
48
49 194 27.5%; rarely or never: 49.7%), and lower proportion of habitual smokers (27.3%)
50
51 195 when compared with the other 2 groups (all: $P < 0.001$). In contrast, the fast-eating
52
53 196 group had a significantly lower proportion of women (27.3%, $P < 0.001$), but a
54
55 197 significantly higher mean BMI (25.0 ± 4.4 , $P < 0.001$) and higher proportion of obese
56
57 198 individuals (44.8%, $P < 0.001$).

1
2
3 199 Table 2 shows the estimated odds ratios (ORs) of the various determinants of
4
5 200 obesity derived from the generalized estimating equation model. All eating habit
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7 201 items, alcohol consumption frequency, sleep adequacy, and obesity status in the
8
9 202 previous checkup were significantly associated with obesity. When compared with the
10
11 203 fast-eating group, the slower eating speeds were significantly associated with reduced
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13 204 ORs for obesity (normal: 0.71; slow: 0.58; $P < 0.001$). The results also showed that
14
15 205 reduced alcohol consumption frequency was significantly associated with higher ORs
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17 206 for obesity (occasionally: 1.18; rarely or never: 1.22; $P < 0.001$). In addition,
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19 207 inadequate sleep was significantly associated with a higher OR for obesity (1.06, $P =$
20
21 208 0.007). Habitual smoking was also significantly associated with the outcome.

22
23 209 The estimated coefficients of the various determinants of changes in BMI are
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25 210 presented in Table 3. Eating speed (normal: $P < 0.001$; slow: $P < 0.001$), eating
26
27 211 dinner within 2 hours before sleeping for 3 times or more per week ($P < 0.001$),
28
29 212 snacking after dinner for 3 times or more per week ($P < 0.001$), BMI in the previous
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31 213 checkup ($P < 0.001$), alcohol consumption frequency (occasionally: $P < 0.001$; rarely
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33 214 or never: $P = 0.002$), sleep adequacy ($P < 0.001$), and age ($P = 0.008$) were
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35 215 significantly associated with changes in BMI. With the exception of age and BMI in
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37 216 the previous checkup, the coefficients of all the other factors were negative. This
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39 217 indicated that eating slower, not eating dinner within 2 hours before sleeping, not
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41 218 snacking after dinner, drinking infrequently, and not obtaining adequate sleep were
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43 219 associated with reductions in BMI. Skipping breakfast 3 times or more per week,
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45 220 habitual smoking, and the use of anti-diabetic medication were not significantly
46
47 221 associated with BMI.

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50 223 **Discussion**

51
52 224 This study analyzed Japanese men and women who had undergone specific health
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54 225 checkups regardless of obesity status. Possible lifestyle-related determinants of
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56 226 obesity were identified using questionnaire items from the Standard Health Checkup

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3 227 and Counseling Guidance Program.¹² We examined 6-year panel data to determine
4 228 how changes in eating speed and other lifestyle habits affect obesity and BMI. The
5 229 main results indicated that decreases in eating speeds can lead to reductions in
6
7 230 obesity and BMI after controlling for the covariates. In addition, the study found that
8
9 231 the cessation of eating after dinner or within 2 hours before sleeping would also have
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11 232 a similar effect on reducing excess body weight.
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14 233 A strength of this study is the utilization of large-scale panel data from
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16 234 approximately 60,000 diabetes patients spanning a 6-year observation period. The use
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18 235 of panel data increases the accuracy of estimates when compared with conventional
19
20 236 cross-sectional and time series data.¹⁷ Panel data also enable adjustments of the
21
22 237 unobservable differences between study subpopulations, thereby facilitating analyses
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24 238 of the effects of behavioral changes in subjects. Another strength of this study is the
25
26 239 incorporation of data on lifestyle habits, such as eating, sleeping, and smoking. By
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28 240 analyzing the associations between these habits and obesity, our study was able to
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30 241 quantify the possible effects of changes in these habits on obesity.
31

32 242 The major finding of this study is that changes in eating speed can affect
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34 243 obesity and BMI. The control of eating speed may therefore be a possible means of
35
36 244 regulating body weight and preventing obesity, which in turn reduces the risk of
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38 245 developing noncommunicable diseases. Eating quickly is associated with impaired
39
40 246 glucose tolerance and insulin resistance,^{18,19} and is a known risk factor for diabetes
41
42 247 through increases in body weight.²⁰ Other studies have also reported associations
43
44 248 between eating quickly and increased BMI, indicating that eating speed is a
45
46 249 contributing factor for obesity.^{7,8,21-26} A possible reason for this association is that
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48 250 fast eaters may continue to eat until they feel full despite having already consumed an
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50 251 adequate amount of calories, and the combined effect of eating quickly and
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52 252 overeating may contribute to weight gain.²⁷ In contrast, eating slowly may help to
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54 253 increase feelings of satiety before an excessive amount of food is ingested.²⁸⁻³⁰ A
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56 254 prospective study of schoolgirls found that the reduction of eating speed was able to
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255 suppress weight gain and prevent obesity.³¹ The findings of these studies are
256 consistent with those of our analysis.

257 In addition to BMI-based definitions of obesity, waist circumference–based
258 definitions of abdominal obesity have also become increasingly important in recent
259 years. Cerhan *et al.* proposed that assessments of waist circumference should
260 accompany assessments of BMI.³² As a supplementary analysis, we employed a fixed-
261 effects model to examine the effects of changes in eating speed on waist
262 circumference in our subjects. The results showed that when compared with fast
263 eaters, normal-speed eaters and slow eaters had reductions in waist circumference of
264 0.21 cm and 0.41 cm, respectively ($P < 0.001$). These results support our findings of
265 the effects of changes in eating speed on obesity.

266 Our results also indicated that frequently eating dinner within 2 hours before
267 sleeping, snacking after dinner, and skipping breakfast contribute to the development
268 of obesity. Previous studies have identified eating after dinner and within 2 hours
269 before sleeping as risk factors of metabolic syndrome.⁷ This supports our findings
270 that the cessation of these habits can help to reduce obesity and BMI. Skipping
271 breakfast has also been shown to be associated with excess weight and obesity, and is
272 a risk factor of metabolic syndrome.^{7,9,33} Our generalized estimating equation model
273 revealed that consistently eating breakfast can reduce obesity, which also
274 corroborates the findings of previous studies. However, our fixed-effects model
275 showed that consistently eating breakfast did not affect changes in BMI. It has been
276 reported that skipping breakfast over a long-period is associated with high BMI and
277 elevated cardiometabolic risks.³⁴ Consistently eating breakfast may therefore help to
278 control obesity and BMI.

279 Daily alcohol consumption has been reported to be positively associated with
280 obesity, and is another risk factor of metabolic syndrome.^{7,35} However, our findings
281 indicated that alcohol consumption frequency was not significantly associated with
282 obesity. Previous studies have reported that the frequency of alcohol consumption

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3 283 (given the same quantities of alcohol) was inversely associated with obesity.^{36,37} It is
4 284 possible that the subjects in this study who drank with higher frequency were
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6 285 consuming moderate quantities of alcohol, whereas the subjects who drank
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8 286 infrequently consumed larger quantities during each session.
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11 287 Studies have also found associations between short sleep durations and BMI
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13 288 increases, and that poor-quality sleep is associated with metabolic syndrome.³⁸⁻⁴⁰ Our
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15 289 analysis produced contradictory results in that a change from adequate sleep to
16
17 290 inadequate sleep would reduce BMI but increase obesity progression. A recent study
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19 291 has shown that unstable sleep patterns may increase the quantity of food intake,⁴¹ and
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21 292 our findings therefore require further investigation. The lack of association between
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23 293 habitual smoking and BMI or metabolic syndrome has been reported in previous
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25 294 studies,^{7,42} which corroborates our findings.

26
27 295 This study has several limitations that should be considered. First, this study
28
29 296 utilized health checkup data from health insurance societies. As a result, the data may
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31 297 not have included a large proportion of the insurance enrollees' dependents. In
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33 298 particular, there was a relatively small proportion of older adults in our study
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35 299 population. The results may therefore lack generalizability to other subpopulations.
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37 300 Second, eating speed and the other lifestyle habits were self-assessed, and may
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39 301 therefore be vulnerable to reporting bias. However, while the differences in
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41 302 perceptions of eating and sleeping habits in standardized questionnaires have been
42
43 303 described,⁴³ Sasaki *et al.* reported that there was no difference between the eating
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45 304 speeds assessed by study subjects or by friends of the subjects.²⁵ In addition, our
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47 305 findings are consistent with those of a previous study that used objective measures of
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49 306 eating speed and found that slower eating speeds were associated with greater weight
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51 307 loss.³⁰ Thirdly, we did not include an analysis of physical exercise and energy intake,
52
53 308 which may be potential confounders. Nevertheless, a previous analysis has reported
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55 309 that eating speed was associated with obesity regardless of the level of physical
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57 310 activity.²⁶ Other studies have also reported similar associations between eating speed

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3 311 and BMI given similar overall food intake, which corroborates our findings.^{24,25}
4 312 Therefore, these 2 factors are unlikely to be confounders in this study despite their
5 313 association with BMI. Finally, the sample comprised relatively health-conscious
6 314 individuals who voluntarily participated in health checkups. The findings may
7 315 therefore have limited applicability to less health-conscious people.

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12 316 Many studies have shown that eating habits are associated with BMI and weight
13 317 gain.^{7,8,18-31} However, this study utilized panel data to show that changes in eating
14 318 habits have a strong relationship with obesity and BMI. These findings indicate that
15 319 weight loss can be supported through the reduction of eating speed, the cessation of
16 320 eating dinner within 2 hours before sleeping, the cessation of snacking after dinner,
17 321 and consistently having breakfast.

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23 323 **Conclusions**

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26 324 Changes in eating habits can affect obesity and BMI. Interventions aimed at altering
27 325 eating habits, such as education initiatives and programs to reduce eating speed, may
28 326 be useful in preventing obesity and reducing the risk of noncommunicable diseases.

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8 331 010)

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11
12 333 **Competing interests:**

13
14 334 No potential conflicts of interest relevant to this article were reported.
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18 336 **Author contributions:**

19
20 337 YH contributed to data analysis and interpretation, and drafting of the manuscript. HF
21
22 338 contributed to the study concept, design, and interpretation, and drafting of the
23
24 339 manuscript.
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28 341 **Ethics approval:**

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30 342 This study was approved by the ethics committee of the Japan Medical Data Center.
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34 344 **Data sharing statement:**

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36 345 No additional data are available.
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466 **Table 1. Distribution of baseline characteristics according to eating speed**

	Eating Speed			P
	Fast (n = 22,062)	Normal (n = 33,460)	Slow (n = 4,191)	
Number of checkups	4.2 [1.5]	4.2 [1.6]	4.4 [1.6]	<0.001 ^b
Women	6,023 (27.3%)	12,213 (36.5%)	1,861 (44.4%)	<0.001 ^a
Age	46.6 [10.4]	48.1 [10.6]	46.5 [11.7]	<0.001 ^b
Use of anti-diabetic medications	13,648 (61.8%)	20,074 (60%)	2,525 (60.2%)	<0.001 ^a
BMI, kg/m ²	25 [4.4]	23.4 [4.0]	22.3 [4.0]	<0.001 ^b
Obese (BMI ≥25)	9,884 (44.8%)	9,886 (29.6%)	901 (21.5%)	<0.001 ^a
Eating dinner within 2 hours before sleeping ≥3 times per week	9,545 (43.3%)	11,161 (33.4%)	1,541 (36.8%)	<0.001 ^a
Snacking after dinner ≥3 times per week	4,247 (19.2%)	4,851 (14.5%)	809 (19.3%)	<0.001 ^a
Skipping breakfast ≥3 times per week	4,599 (20.8%)	5,542 (16.6%)	794 (18.9%)	<0.001 ^a
Alcohol consumption				
Every day	5,695 (25.8%)	8,810 (26.3%)	955 (22.8%)	<0.001 ^a
Occasionally	7,233 (32.8%)	10,398 (31.1%)	1,152 (27.5%)	<0.001 ^a
Rarely or never	9,142 (41.4%)	14,247 (42.6%)	2,085 (49.7%)	<0.001 ^a
Obtain adequate sleep	10,834 (49.1%)	18,437 (55.1%)	2,238 (53.4%)	<0.001 ^a
Habitual smoker	7,140 (32.4%)	10,239 (30.6%)	1,146 (27.3%)	<0.001 ^a

467 ^a χ^2 test468 ^b One-way analysis of variance469 Values for number of checkups, age, and BMI are presented as mean [standard deviation]. All
470 other values are presented as number of subjects (proportion of each eating-speed group).

471 Abbreviation: BMI, body mass index.

472 **Table 2. Estimated odds ratios of the determinants of obesity derived from the**
 473 **generalized estimating equation model**

	Odds Ratio	95% Confidence Intervals	P
Eating speed			
Fast	REF		
Normal	0.71	0.68 - 0.75	<0.001
Slow	0.58	0.54 - 0.63	<0.001
Eating dinner within 2 hours before sleeping ≥ 3 times per week			
Yes	REF		
No	0.90	0.86 - 0.94	<0.001
Snacking after dinner ≥ 3 times per week			
Yes	REF		
No	0.85	0.80 - 0.90	<0.001
Skipping breakfast ≥ 3 times per week			
Yes	REF		
No	0.92	0.87 - 0.97	0.003
Alcohol consumption			
Every day	REF		
Occasionally	1.18	1.12 - 1.25	<0.001
Rarely or never	1.22	1.16 - 1.29	<0.001
Obtain adequate sleep			
Yes	REF		
No	1.06	1.02 - 1.11	0.007
Habitual smoker			
Yes	REF		
No	1.10	1.05 - 1.15	<0.001
Use of anti-diabetic medication			
No	REF		
Yes	1.02	0.98 - 1.07	0.293
Age	1.00	1.00 - 1.00	0.076
Female	0.66	0.63 - 0.69	<0.001
Obesity status in the previous checkup			
Not obese	REF		
Obese	164.79	156.15 - 173.91	<0.001

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475 **Table 3. Estimated coefficients of the determinants of changes in BMI derived**
 476 **from the fixed-effects model**

	Coefficient	95% Confidence Intervals	P
Eating speed			
Fast	REF		
Normal	-0.07	-0.10, -0.05	<0.001
Slow	-0.11	-0.15, -0.06	<0.001
Eating dinner within 2 hours before sleeping ≥ 3 times per week			
Yes	REF		
No	-0.06	-0.08, -0.04	<0.001
Snacking after dinner ≥ 3 times per week			
Yes	REF		
No	-0.08	-0.11, -0.06	<0.001
Skipping breakfast ≥ 3 times per week			
Yes	REF		
No	0.00	-0.03, 0.04	0.818
Alcohol consumption			
Every day	REF		
Occasionally	-0.10	-0.13, -0.06	<0.001
Rarely or never	-0.17	-0.22, -0.13	0.002
Obtain adequate sleep			
Yes	REF		
No	-0.03	-0.05, -0.01	0.001
Habitual smoker			
Yes	REF		
No	0.23	0.20, 0.27	0.363
Use of anti-diabetic medication			
No	REF		
Yes	-0.12	-0.14, -0.10	0.069
Age	0.08	0.07, 0.10	0.008
BMI in the previous checkup	0.09	0.07, 0.10	<0.001

477 Abbreviation: BMI, body mass index.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No.	Recommendation	Page No.	Relevant text from manuscript
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	Page 1: Title	
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 1: Abstract	
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 4: Lines 72-77&Lines 84-86	
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 4: Lines 90-92	
Methods				
Study design	4	Present key elements of study design early in the paper	Page 5: Lines 111-120	
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 4-5: Lines 95-109	
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	Page 5: Lines 112-114	
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	Not Applicable	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 5-6: Lines 122-157	
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	Page 4-5: Lines 95-109	
Bias	9	Describe any efforts to address potential sources of bias	Not Applicable	
Study size	10	Explain how the study size was arrived at	Not Applicable	

Continued on next page

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 5-6: Lines 122-157
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Page 7-8: Lines 159-179
		(b) Describe any methods used to examine subgroups and interactions	Not Applicable
		(c) Explain how missing data were addressed	Page 6: Lines 118-119
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed	Not Applicable
		<i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	
		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	Not Applicable
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: Lines 181-187
		(b) Give reasons for non-participation at each stage	Not Applicable
		(c) Consider use of a flow diagram	Not Applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 20: Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Page 20: Lines 181-187
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	Page 20: Line 183-184
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	Page 20: Table 1
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	Page 20: Table 1
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	Page 20: 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 21-22: Table 2 & Table 3
		(b) Report category boundaries when continuous variables were categorized	Page 7: Lines 145-157
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not Applicable

Continued on next page

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Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not Applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 9-10: Lines 221-229
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 12-13: Lines 291-311
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 10: Lines 239-252
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 12: Lines 291-295
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 14: Lines 324-326

*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.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

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The effects of changes in eating speed on obesity in patients with diabetes: a secondary analysis of longitudinal health checkup data

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Manuscripts

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7 3 **The effects of changes in eating speed on obesity in patients with diabetes:**
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9 4 **a secondary analysis of longitudinal health checkup data**
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22 Abstract

23 **Objective** Few studies have examined the causal relationships between lifestyle
24 habits and obesity. With a focus on eating speed in patients with type 2 diabetes, this
25 study aimed to analyze the effects of changes in lifestyle habits on changes in obesity
26 utilizing panel data.

27 **Methods** Patient-level panel data from 2008 to 2013 were generated using
28 commercially available insurance claims data and health checkup data. The study
29 subjects comprised Japanese men and women (n=59,717) enrolled in health insurance
30 societies who had been diagnosed with type 2 diabetes during the study period. Body
31 mass index (BMI) was measured, and obesity was defined as a BMI of 25 or more.
32 Information on lifestyle habits were obtained from the subjects' responses to
33 questions asked during health checkups. The main exposure of interest was eating
34 speed ("fast", "normal", and "slow"). Other lifestyle habits included eating dinner
35 within 2 hours of sleeping, after-dinner snacking, skipping breakfast, alcohol
36 consumption frequency, sleep adequacy, and tobacco consumption. A generalized
37 estimating equation model was used to examine the effects of these habits on obesity.
38 In addition, fixed-effects models were used to assess these effects on BMI and waist
39 circumference.

40 **Results** The generalized estimating equation model showed that eating slower
41 inhibited the development of obesity. The odds ratios for slow (0.58) and normal-
42 speed eaters (0.71) indicated that these groups were less likely to be obese than fast
43 eaters ($P < 0.001$). Similarly, the fixed-effects models showed that eating slower
44 reduced BMI and waist circumference. Relative to fast eaters, the coefficients of the
45 BMI model for slow and normal-speed eaters were -0.11 and -0.07, respectively ($P <$
46 0.001).

47 **Discussion** Changes in eating speed can affect changes in obesity, BMI, and waist
48 circumference. Interventions aimed at reducing eating speed may be effective in
49 preventing obesity and lowering the associated health risks.

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Keywords: Body mass index, obesity, eating habits, health checkups

For peer review only

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3 53 **Strengths and limitations of this study**

- 4 54 1. This is the first panel data analysis to verify the effects of changes in eating
5 55 habits on obesity.
6
7 56 2. Long-term large-scale longitudinal data were used.
8
9 57 3. Lifestyle habits were self-assessed and may be vulnerable to reporting bias.
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11 58 4. The sample comprised relatively health-conscious individuals who voluntarily
12 59 participated in health checkups, and the findings may therefore have limited
13 60 applicability to less health-conscious people.
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62 Introduction

63 Excess body weight and obesity can lead to an increased risk of developing
64 noncommunicable diseases such as diabetes, cardiovascular disease, and various
65 forms of cancer.¹⁻⁴ Studies have reported that the regulation of body weight can be
66 effective in lowering these health risks.¹⁻⁴ However, a 10-year longitudinal study of
67 Japanese men aged 40 to 69 years found that the proportion of overweight and obese
68 individuals had increased over the study period.⁵ In addition, the Japanese
69 government's *Annual Health, Labour and Welfare Report 2014* noted that the
70 prevalence of obesity continues to rise, with a substantially higher prevalence among
71 men in 2012 than in 1982.⁶ The report also revealed that obesity prevalence exceeded
72 30% in men in their 40s and 50s. These figures suggest that current obesity
73 prevention efforts in Japan may be inadequate.

74 The fundamental cause of excess weight gain is the failure to ensure a balance
75 between energy intake and energy expenditure.¹ However, recent studies have
76 reported that excess weight gain and metabolic syndrome are affected not only by
77 energy intake, but are also influenced by other factors such as eating speed, eating
78 frequency, and other lifestyle habits.⁷⁻¹⁰ In addition to emphasizing the importance of
79 balancing energy intake and expenditure, these other factors represent possible targets
80 for obesity prevention measures.

81 In response to the rising prevalence of obesity, Japan's Ministry of Health,
82 Labour and Welfare introduced a nationwide health screening program (Standard
83 Health Checkup and Counseling Guidance Program) to detect risk factors for obesity
84 and metabolic syndrome.^{11,12} Under this program, insurers conduct "specific health
85 checkups" aimed at insurance enrollees aged 40 years or older. However, participation
86 in these checkups is not mandatory.

87 Although many studies have addressed the associations between lifestyle habits
88 and obesity, few have examined the causal effects of changes in lifestyle habits on
89 obesity. In addition, studies from Japan have shown that the number of persons with

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3 90 type 2 diabetes has increased with increasing BMI¹³, and that BMI is an independent
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5 91 risk factor for this condition¹⁴. This study focuses on persons with type 2 diabetes as
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7 92 they are likely to benefit directly from health improvements arising from the
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9 93 alleviation of obesity. The main objective of this study was to utilize panel data to
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11 94 analyze the effects of changes in eating speed and other lifestyle habits on obesity in
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13 95 patients with type 2 diabetes. For this analysis, we hypothesized that slower eating
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15 96 speeds would reduce obesity.

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18 98 **Methods**

19 99 **Data source**

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22 100 This study used a commercial database obtained from the Japan Medical Data Center
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24 101 (JMDC), a for-profit organization that collects, curates, and distributes health-related
25
26 102 data. The database comprised insurance claims data and health checkup data for
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28 103 insurance enrollees and their dependents that were collected through JMDC's
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30 104 contracts with several health insurance societies in Japan. The claims data included
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32 105 information on the dates of consultations and treatments, sex, age, diagnoses, specific
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34 106 treatments, and healthcare expenditure. The health checkup data included the dates of
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36 107 checkups, body mass index (BMI), waist circumference, blood pressure, and the
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38 108 results of blood chemical analysis, liver function test, blood glucose test, and
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40 109 urinalysis. The health checkup data also included the subjects' responses to several
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42 110 questions regarding lifestyle factors, such as eating habits, alcohol consumption,
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44 111 tobacco use, and sleeping habits.¹² The claims data and health checkup data were
45
46 112 linked at the individual subject level for analysis. Approval for this study (No. 18-09-
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48 113 2014) was obtained from the ethics committee of the JMDC.

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51 115 **Study design**

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54 116 We first identified subjects with at least one recorded diagnosis of type 2 diabetes in
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56 117 their claims data from January 2005 to June 2013 using the corresponding

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3 118 International Classification of Diseases, 10th revision codes (E10–E14). Both the
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5 119 claims data and health checkup data from this study period were used in the analysis.
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7 120 From the claims data, we obtained information on subject sex, age, and the starting
8
9 121 date of anti-diabetic medication. The claims data were linked with the health checkup
10
11 122 data at the patient-month level to generate panel data. We excluded subjects with
12
13 123 missing data for BMI and lifestyle habits. The results from each subject’s first
14
15 124 specific health checkup during the study period were used as the baseline values.
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18 126 **Outcomes**

19
20 127 The primary outcome of this study was obesity status. According to the World Health
21
22 128 Organization’s criteria, a BMI of 25 or more indicates that a person is overweight,
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24 129 and a BMI of 30 or more indicates obesity. However, it has been proposed that these
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26 130 BMI cut-off points should be lower for Asian populations.¹⁵ The Japan Society for the
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28 131 Study of Obesity has recommended that obesity be defined by a BMI of 25 or more
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30 132 for the Japanese population.¹⁶ In accordance with this recommendation, our study
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32 133 uses a BMI cut-off point of 25 to identify obese individuals. The secondary outcomes
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34 134 of this study were BMI and waist circumference, which were analyzed as continuous
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36 135 variables.
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39 137 **Exposure variables**

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41
42 138 The exposure variables consisted of the 7 question items regarding lifestyle habits.
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44 139 The main exposure of interest was eating speed. The other items were eating dinner
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46 140 within 2 hours before sleeping for 3 times or more per week, snacking after dinner for
47
48 141 3 times or more per week, skipping breakfast 3 times or more per week, alcohol
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50 142 consumption frequency, sleep adequacy, and habitual smoking. These variables were
51
52 143 analyzed as categorical variables based on the response options. Eating speed was
53
54 144 analyzed as 3 categories (“fast”, “normal”, and “slow”). Eating dinner within 2 hours
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56 145 before sleeping for 3 times or more per week, snacking after dinner for 3 times or

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3 146 more per week, skipping breakfast 3 times or more per week, adequate sleep, and
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5 147 habitual smoking were analyzed as 2 categories (“yes” and “no”). Alcohol
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7 148 consumption frequency was analyzed as 3 categories (“every day”, “occasionally”,
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9 149 and “rarely or never”).

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12 151 **Covariates**

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14 152 The covariates were selected from factors thought to influence lifestyle habits and
15
16 153 weight management. These included the use of anti-diabetic medication (as an
17
18 154 indicator of diabetes that requires pharmacologic treatment), age, as well as obesity
19
20 155 status and BMI in the previous checkup. The use or non-use of anti-diabetic
21
22 156 medication was determined based on whether the patient had been administered anti-
23
24 157 diabetic medication at the time of each health checkup. This variable was analyzed as
25
26 158 2 categories (“yes” and “no”). In addition to human insulin preparations and insulin
27
28 159 analogs, anti-diabetic medications also included sulfonylureas, biguanide derivatives,
29
30 160 glitazones, α -glucosidase inhibitors, glinides, DPP-4 inhibitors, and GLP-1 receptor
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32 161 agonists. Age and BMI in the previous checkup were analyzed as continuous variables.
33
34 162 Obesity status in the previous checkup was analyzed as 2 categories (“yes” for BMI
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36 163 ≥ 25 and “no” for BMI < 25).

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39 165 **Statistical analysis**

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41 166 The subject baseline characteristics of sex, age, BMI, obesity status, waist
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43 167 circumference, and lifestyle habits were compared among the 3 eating speed
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45 168 categories using the χ^2 test or one-way analysis of variance. Patient-level panel data
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47 169 were generated using repeated estimates from multiple health checkups. This study
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49 170 used longitudinal data from annual health checkups collected over approximately 6
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51 171 years. The application of panel data enables the estimation of changes in the
52
53 172 dependent variables that result from changes in eating speed (e.g., fast to fast, fast to
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55 173 normal, fast to slow, and so on) in individual subjects.

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2
3 174 We first constructed a generalized estimating equation model to elucidate the
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5 175 effects of changes in eating speed on obesity. The exposure variables were the 7
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7 176 lifestyle habit items, and the covariates were the use of anti-diabetic medication, age,
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9 177 sex, and obesity status in the previous checkup.

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11 178 In order to estimate the influence of changes in eating speed on BMI and waist
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13 179 circumference, we utilized fixed-effects models with these factors as the dependent
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15 180 variables. The exposure variables were the 7 lifestyle habit items, and the covariates
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17 181 were the use of anti-diabetic medication, age, and BMI or waist circumference in the
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19 182 previous checkup. Sex and other covariates that remained unchanged throughout the
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21 183 observation period were adjusted as fixed effects. The Hausman test was employed
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23 184 for model selection; the *P*-value was below 0.001, which confirmed that the use of the
24
25 185 fixed-effects model was appropriate.

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27 186 All statistical analyses were conducted using Stata 13.1 (Stata Corp., College
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29 187 Station, TX, USA). Statistical significance was set at $P < 0.05$.

30 31 32 189 **Results**

33
34 190 We identified 92,363 individuals from 303,361 person-months who had been
35
36 191 diagnosed with type 2 diabetes and had health checkup data for the period between
37
38 192 January 2005 and June 2013. After excluding cases with missing data in BMI and the
39
40 193 lifestyle habit items, the sample for analysis comprised 59,717 individuals from
41
42 194 129,978 person-months. The claims data and health checkup data that could be linked
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44 195 for analysis covered the period from February 2008 to June 2013.

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46 196 The distribution of baseline characteristics according to eating speed is
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48 197 presented in Table 1. The slow-eating group had a significantly higher proportion of
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50 198 women (44.4%), lower mean BMI (22.3 ± 4.0), lower proportion of obese individuals
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52 199 (21.5%), smaller mean waist circumference (80.1 ± 10.6 cm), lower alcohol
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54 200 consumption frequency (every day: 22.8% ; occasionally: 27.5% ; rarely or never:
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56 201 49.7%), and lower proportion of habitual smokers (27.3%) when compared with the

202 other 2 groups (all: $P < 0.001$). In contrast, the fast-eating group had a significantly
203 lower proportion of women (27.3%, $P < 0.001$), but a significantly higher mean BMI
204 (25.0 ± 4.4 , $P < 0.001$), higher proportion of obese individuals (44.8%, $P < 0.001$), and
205 larger mean waist circumference (86.8 ± 11.1 cm, $P < 0.001$).

206 The mean number (and standard deviation) of health checkups among the 59,171
207 subjects used in the panel data analysis was 1.9 (1.1). The distribution of subjects
208 (and percentage of all subjects) according to the number of health checkups
209 undergone during the study period was as follows: 21,805 subjects (36.5%) with 1
210 checkup, 17,694 (29.6%) subjects with 2 checkups, 12,075 (20.2%) subjects with 3
211 checkups, 4,524 (7.6%) subjects with 4 checkups, 3,248 (5.4%) subjects with 5
212 checkups, and 371 (0.6%) subjects with 6 checkups. Table 2 shows the changes in
213 eating speed across these checkups according to the different baseline eating speeds.
214 Approximately half (51.9%) of the subjects exhibited changes in eating speed from
215 baseline during the study period. The results showed that 171 subjects (0.29%)
216 changed from being fast eaters to slow eaters, whereas 92 subjects (0.15%) changed
217 from being slow eaters to fast eaters.

218 Table 3 shows the estimated odds ratios (ORs) of the various determinants of
219 obesity derived from the generalized estimating equation model. All eating habit
220 items, alcohol consumption frequency, sleep adequacy, and obesity status in the
221 previous checkup were significantly associated with obesity. When compared with the
222 fast-eating group, the slower eating speeds were significantly associated with reduced
223 ORs for obesity (normal: 0.71; slow: 0.58; $P < 0.001$). The results also showed that
224 reduced alcohol consumption frequency was significantly associated with higher ORs
225 for obesity (occasionally: 1.18; rarely or never: 1.22; $P < 0.001$). In addition,
226 adequate sleep was significantly associated with a lower OR for obesity (0.94, $P =$
227 0.007). Habitual smoking was also significantly associated with the outcome.

228 The estimated coefficients of the various determinants of changes in BMI are
229 presented in Table 4. Eating speed (normal: $P < 0.001$; slow: $P < 0.001$), eating

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3 230 dinner within 2 hours before sleeping for 3 times or more per week ($P < 0.001$),
4 231 snacking after dinner for 3 times or more per week ($P < 0.001$), BMI in the previous
5 232 checkup ($P < 0.001$), alcohol consumption frequency (occasionally: $P < 0.001$; rarely
6 233 or never: $P = 0.002$), and age ($P = 0.008$) were significantly associated with changes
7 234 in BMI. With the exception of inadequate sleep, habitual smoking, age, and BMI in
8 235 the previous checkup, the coefficients of all the other factors were negative. This
9 236 indicated that eating slower, not eating dinner within 2 hours before sleeping, not
10 237 snacking after dinner, and drinking infrequently were associated with reductions in
11 238 BMI. Skipping breakfast 3 times or more per week, habitual smoking, and the use of
12 239 anti-diabetic medication were not significantly associated with BMI.

13 240 Table 5 presents the results of eating speed on waist circumference from the
14 241 fixed-effects model analysis. When compared with fast eaters, normal-speed eaters
15 242 and slow eaters had reductions in waist circumference of 0.21 cm and 0.41 cm,
16 243 respectively ($P < 0.001$).

17 244

18 245 **Discussion**

19 246 This study analyzed Japanese men and women who had undergone specific health
20 247 checkups regardless of obesity status. Possible lifestyle-related determinants of
21 248 obesity were identified using questionnaire items from the Standard Health Checkup
22 249 and Counseling Guidance Program.¹² We examined 6-year panel data to determine
23 250 how changes in eating speed and other lifestyle habits affect obesity and BMI. The
24 251 main results indicated that decreases in eating speeds can lead to reductions in
25 252 obesity and BMI after controlling for the covariates. In addition, the study found that
26 253 the cessation of eating after dinner or within 2 hours before sleeping would also have
27 254 a similar effect on reducing excess body weight.

28 255 A strength of this study is the utilization of large-scale panel data from
29 256 approximately 60,000 diabetes patients spanning a 6-year observation period. The use
30 257 of panel data increases the accuracy of estimates when compared with conventional

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3 258 cross-sectional and time series data.¹⁷ Panel data also enable adjustments of the
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5 259 unobservable differences between study subpopulations, thereby facilitating analyses
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7 260 of the effects of behavioral changes in subjects. Another strength of this study is the
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9 261 incorporation of data on lifestyle habits, such as eating, sleeping, and smoking. By
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11 262 analyzing the associations between these habits and obesity, our study was able to
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13 263 quantify the possible effects of changes in these habits on obesity.

14
15 264 The major finding of this study is that changes in eating speed can affect
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17 265 obesity, BMI, and waist circumference. The control of eating speed may therefore be
18
19 266 a possible means of regulating body weight and preventing obesity, which in turn
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21 267 reduces the risk of developing noncommunicable diseases. Eating quickly is
22
23 268 associated with impaired glucose tolerance and insulin resistance,^{18,19} and is a known
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25 269 risk factor for diabetes through increases in body weight.²⁰ Other studies have also
26
27 270 reported associations between eating quickly and increased BMI, indicating that
28
29 271 eating speed is a contributing factor for obesity.^{7,8,21-26} A possible reason for this
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31 272 association is that fast eaters may continue to eat until they feel full despite having
32
33 273 already consumed an adequate amount of calories, and the combined effect of eating
34
35 274 quickly and overeating may contribute to weight gain.²⁷ In contrast, eating slowly
36
37 275 may help to increase feelings of satiety before an excessive amount of food is
38
39 276 ingested.²⁸⁻³⁰ A prospective study of schoolgirls found that the reduction of eating
40
41 277 speed was able to suppress weight gain and prevent obesity.³¹ The findings of these
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43 278 studies are consistent with those of our analysis.

44
45 279 In addition to BMI-based definitions of obesity, waist circumference-based
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47 280 definitions of abdominal obesity have also become increasingly important in recent
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49 281 years. Cerhan *et al.* proposed that assessments of waist circumference should
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51 282 accompany assessments of BMI.³² As a supplementary analysis, we employed a fixed-
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53 283 effects model to examine the effects of changes in eating speed on waist
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55 284 circumference in our subjects. The results showed that when compared with fast
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57 285 eaters, normal-speed eaters and slow eaters had reductions in waist circumference of

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3 286 0.21 cm and 0.41 cm, respectively ($P < 0.001$). These results support our findings of
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5 287 the effects of changes in eating speed on obesity.

6
7 288 Our results also indicated that frequently eating dinner within 2 hours before
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9 289 sleeping, snacking after dinner, and skipping breakfast contribute to the development
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11 290 of obesity. Previous studies have identified eating after dinner and within 2 hours
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13 291 before sleeping as risk factors of metabolic syndrome.⁷ This supports our findings
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15 292 that the cessation of these habits can help to reduce obesity and BMI. Skipping
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17 293 breakfast has also been shown to be associated with excess weight and obesity, and is
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19 294 a risk factor of metabolic syndrome.^{7,9,33} Our generalized estimating equation model
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21 295 revealed that consistently eating breakfast can reduce obesity, which also
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23 296 corroborates the findings of previous studies. However, our fixed-effects model
24
25 297 showed that consistently eating breakfast did not affect changes in BMI. It has been
26
27 298 reported that skipping breakfast over a long-period is associated with high BMI and
28
29 299 elevated cardiometabolic risks.³⁴ Consistently eating breakfast may therefore help to
30
31 300 control obesity and BMI.

32
33 301 The association between daily alcohol consumption and obesity remains
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35 302 controversial. While several studies have identified this lifestyle habit as a risk factor
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37 303 of metabolic syndrome,^{7,35} others have reported an inverse association between the
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39 304 frequency of alcohol consumption (given the same quantities of alcohol) and
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41 305 obesity.^{36,37} In our study, the frequency of alcohol consumption was found to be
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43 306 inversely associated with obesity, but positively associated with BMI and waist
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45 307 circumference. In order to clarify this apparent disparity, further analyses of alcohol
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47 308 consumption should be conducted with consideration to the overall quantities of
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49 309 alcohol consumed.

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51 310 Studies have also found associations between short sleep durations and BMI
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53 311 increases, and that poor-quality sleep is associated with metabolic syndrome.³⁸⁻⁴⁰ Our
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55 312 analysis produced contradictory results in that a change from adequate sleep to
56
57 313 inadequate sleep would reduce BMI but increase obesity progression. Moreover, we

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3 314 did not detect any significant association between sleep and waist circumference. A
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5 315 recent study has shown that unstable sleep patterns may increase the quantity of food
6
7 316 intake,⁴¹ and our findings therefore require further investigation. The lack of
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9 317 association between habitual smoking and BMI or metabolic syndrome has been
10
11 318 reported in previous studies,^{7,42} which corroborates our findings.

12
13 319 This study has several limitations that should be considered. First, this study
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15 320 utilized health checkup data from health insurance societies. As a result, the data may
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17 321 not have included a large proportion of the insurance enrollees' dependents. In
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19 322 particular, there was a relatively small proportion of older adults in our study
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21 323 population. The results may therefore lack generalizability to other subpopulations.
22
23 324 Second, eating speed and the other lifestyle habits were self-assessed, and may
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25 325 therefore be vulnerable to reporting bias. However, while the differences in
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27 326 perceptions of eating and sleeping habits in standardized questionnaires have been
28
29 327 described,⁴³ Sasaki *et al.* reported that there was no difference between the eating
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31 328 speeds assessed by study subjects or by friends of the subjects.²⁵ In addition, our
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33 329 findings are consistent with those of a previous study that used objective measures of
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35 330 eating speed and found that slower eating speeds were associated with greater weight
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37 331 loss.³⁰ Thirdly, we did not include an analysis of physical exercise and energy intake,
38
39 332 which may be potential confounders. Nevertheless, a previous analysis has reported
40
41 333 that eating speed was associated with obesity regardless of the level of physical
42
43 334 activity.²⁶ Other studies have also reported similar associations between eating speed
44
45 335 and BMI given similar overall food intake, which corroborates our findings.^{24,25}
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47 336 Therefore, these 2 factors are unlikely to be confounders in this study despite their
48
49 337 association with BMI. Finally, the sample comprised relatively health-conscious
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51 338 individuals who voluntarily participated in health checkups. The findings may
52
53 339 therefore have limited applicability to less health-conscious people.

54
55 340 Many studies have shown that eating habits are associated with BMI and weight
56
57 341 gain.^{7,8,18-31} However, this study utilized panel data to show that changes in eating

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3 342 habits have a strong relationship with obesity, BMI, and waist circumference. These
4 343 findings indicate that weight loss can be supported through the reduction of eating
5 344 speed, the cessation of eating dinner within 2 hours before sleeping, the cessation of
6 345 snacking after dinner, and consistently having breakfast.
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11
12 347 **Conclusions**

13
14 348 Changes in eating habits can affect obesity, BMI, and waist circumference.

15 349 Interventions aimed at altering eating habits, such as education initiatives and

16 350 programs to reduce eating speed, may be useful in preventing obesity and reducing

17 351 the risk of noncommunicable diseases.
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8 356 010)
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11
12 358 **Competing interests:**

13
14 359 No potential conflicts of interest relevant to this article were reported.
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17 361

18 362 **Author contributions:**

19
20 363 YH contributed to data analysis and interpretation, and drafting of the manuscript. HF
21
22 364 contributed to the study concept, data design and interpretation, and drafting of the
23
24 365 manuscript.
25

26 366

27 367 **Ethics approval:**

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29 368 This study was approved by the ethics committee of the Japan Medical Data Center
30
31 369 (No. 18-09-2014).
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34 371 **Data sharing statement:**

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36 372 No additional data are available.
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492 **Table 1. Distribution of baseline characteristics according to eating speed**

	Eating Speed			<i>P</i>
	Fast (n = 22,070)	Normal (n = 33,455)	Slow (n = 4,192)	
Women	6,023 (27.3%)	12,213 (36.5%)	1,861 (44.4%)	<0.001 ^a
Age	46.6 [10.4]	48.1 [10.6]	46.5 [11.7]	<0.001 ^b
Use of anti-diabetic medications	13,648 (61.8%)	20,074 (60.0%)	2,525 (60.2%)	<0.001 ^a
BMI, kg/m ²	25.0 [4.4]	23.4 [3.9]	22.3 [4.0]	<0.001 ^b
Obese (BMI ≥25)	9,884 (44.8%)	9,886 (29.6%)	901 (21.5%)	<0.001 ^a
Waist circumference (cm)	86.8 [11.1]	82.8 [10.4]	80.1 [10.6]	<0.001 ^b
Eating dinner within 2 hours before sleeping ≥3 times per week	9,546 (43.3%)	11,161 (33.4%)	1,541 (36.8%)	<0.001 ^a
Snacking after dinner ≥3 times per week	4,247 (19.2%)	4,851 (14.5%)	809 (19.3%)	<0.001 ^a
Skipping breakfast ≥3 times per week	4,599 (20.8%)	5,542 (16.6%)	794 (18.9%)	<0.001 ^a
Alcohol consumption				
Every day	5,695 (25.8%)	8,810 (26.3%)	955 (22.8%)	<0.001 ^a
Occasionally	7,233 (32.8%)	10,398 (31.1%)	1,152 (27.5%)	<0.001 ^a
Rarely or never	9,142 (41.4%)	14,247 (42.6%)	2,085 (49.7%)	<0.001 ^a
Inadequate sleep	11,236 (50.9%)	15,018 (44.9%)	1,954 (46.6%)	<0.001 ^a
Habitual smoker	7,140 (32.4%)	10,240 (30.6%)	1,146 (27.3%)	<0.001 ^a

493 ^a χ^2 test494 ^b One-way analysis of variance495 Values for number of checkups, age, and BMI are presented as mean [standard deviation]. All
496 other values are presented as number of subjects (proportion of each eating-speed group).

497 Abbreviation: BMI, body mass index.

498 **Table 2. Patterns of changes in eating speed during the intermediate and final phases of**
 499 **analysis according to the different baseline eating speeds**

Intermediate Status	Final Status	Baseline Status		
		Fast	Normal	Slow
Fast	Fast	5018 (8.4%)	605 (1.0%)	23 (0.0%)
Fast	Normal	597 (1.0%)	421 (0.7%)	11 (0.0%)
Fast	Slow	22 (0.0%)	4 (0.0%)	4 (0.0%)
Normal	Fast	715 (1.2%)	825 (1.4%)	15 (0.0%)
Normal	Normal	921 (1.5%)	8451 (14.2%)	259 (0.4%)
Normal	Slow	11 (0.0%)	254 (0.4%)	115 (0.2%)
Slow	Fast	44 (0.1%)	28 (0.0%)	9 (0.0%)
Slow	Normal	46 (0.1%)	447 (0.7%)	244 (0.4%)
Slow	Slow	16 (0.0%)	239 (0.4%)	874 (1.5%)
N.A.	Fast ^a	5839 (9.8%)	1322 (2.2%)	30 (0.1%)
N.A.	Normal ^a	1155 (1.9%)	7749 (13.0%)	350 (0.6%)
N.A.	Slow ^a	32 (0.1%)	417 (0.7%)	800 (1.3%)
N.A.	N.A. ^b	7654 (12.8%)	12693 (21.3%)	1458 (2.4%)

500 Some subjects may report different eating speeds throughout their checkups during the study
 501 period. In addition, subjects who underwent 4 to 6 checkups may have different reported
 502 eating speeds during their intermediate phase (2nd to 5th checkups); in these subjects, the
 503 eating speeds during the intermediate phase were categorized in the following order of
 504 priority: slow, normal, and fast. For example, a subject with both slow and fast eating speeds
 505 reported in the 2nd to 5th checkups would be reflected as having a slow eating speed during
 506 the intermediate phase.

507 ^a Subjects with only 2 eating speed measurements during the study period.

508 ^b Subjects with only 1 eating speed measurement during the study period.

509
 510

511 **Table 3. Estimated odds ratios of the determinants of obesity derived from the**
 512 **generalized estimating equation model**

	Odds Ratio	95% Confidence Intervals	P
Eating speed			
Fast	REF		
Normal	0.71	0.68, 0.75	<0.001
Slow	0.58	0.54, 0.63	<0.001
Eating dinner within 2 hours before sleeping ≥ 3 times per week			
Yes	REF		
No	0.90	0.86, 0.94	<0.001
Snacking after dinner ≥ 3 times per week			
Yes	REF		
No	0.85	0.80, 0.90	<0.001
Skipping breakfast ≥ 3 times per week			
Yes	REF		
No	0.92	0.87, 0.97	0.004
Alcohol consumption			
Every day	REF		
Occasionally	1.18	1.12, 1.25	<0.001
Rarely or never	1.22	1.16, 1.29	<0.001
Inadequate sleep			
Yes	REF		
No	0.94	0.90, 0.98	0.007
Habitual smoker			
Yes	REF		
No	1.10	1.05, 1.15	<0.001
Use of anti-diabetic medication			
No	REF		
Yes	1.02	0.98, 1.07	0.293
Age	1.00	1.00, 1.00	0.076
Female	0.66	0.63, 0.69	<0.001
Obesity status in the previous checkup			
Not obese	REF		
Obese	164.79	156.15, 173.91	<0.001

513

514 **Table 4. Estimated coefficients of the determinants of changes in BMI derived**
 515 **from the fixed-effects model**

	Coefficient	95% Confidence Intervals	P
Eating speed			
Fast	REF		
Normal	-0.07	-0.10, -0.05	<0.001
Slow	-0.11	-0.15, -0.06	<0.001
Eating dinner within 2 hours before sleeping ≥ 3 times per week			
Yes	REF		
No	-0.06	-0.08, -0.04	<0.001
Snacking after dinner ≥ 3 times per week			
Yes	REF		
No	-0.08	-0.11, -0.06	<0.001
Skipping breakfast ≥ 3 times per week			
Yes	REF		
No	0.00	-0.03, 0.04	0.829
Alcohol consumption			
Every day	REF		
Occasionally	-0.10	-0.13, -0.06	<0.001
Rarely or never	-0.18	-0.22, -0.13	<0.001
Inadequate sleep			
Yes	REF		
No	0.03	0.01, 0.05	0.001
Habitual smoker			
Yes	REF		
No	0.23	0.20, 0.27	0.363
Use of anti-diabetic medication			
No	REF		
Yes	-0.12	-0.14, -0.10	0.069
Age	0.08	0.07, 0.10	0.008
BMI in the previous checkup	0.09	0.07, 0.10	<0.001

516 Abbreviation: BMI, body mass index.

517

518 **Table 5. Estimated coefficients of the determinants of changes in waist**
 519 **circumference derived from the fixed-effects model**

	Coefficient	95% Confidence Intervals	P
Eating speed			
Fast	REF		
Normal	-0.21	-0.30, -0.12	<0.001
Slow	-0.41	-0.59, -0.22	<0.001
Eating dinner within 2 hours before sleeping ≥ 3 times per week			
Yes	REF		
No	-0.12	-0.20, -0.04	0.003
Snacking after dinner ≥ 3 times per week			
Yes	REF		
No	-0.2	-0.29, -0.11	<0.001
Skipping breakfast ≥ 3 times per week			
Yes	REF		
No	0.03	-0.11, 0.16	0.674
Alcohol consumption			
Every day	REF		
Occasionally	-0.34	-0.47, -0.20	<0.001
Rarely or never	-0.47	-0.65, -0.29	<0.001
Inadequate sleep			
Yes	REF		
No	0.07	0.00, 0.14	0.053
Habitual smoker			
Yes	REF		
No	0.8	0.66, 0.95	<0.001
Use of anti-diabetic medication			
No	REF		
Yes	-0.32	-0.41, -0.23	<0.001
Age	0.27	0.24, 0.30	<0.001
Waist circumference in the previous checkup	-0.11	-0.12, -0.10	<0.001

520

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No.	Recommendation	Page No.	Relevant text from manuscript
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	Page 1: Title	
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 1: Abstract	
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 4: Lines 72-77&Lines 84-86	
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 4: Lines 90-92	
Methods				
Study design	4	Present key elements of study design early in the paper	Page 5: Lines 111-120	
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 4-5: Lines 95-109	
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	Page 5: Lines 112-114	
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	Not Applicable	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 5-6: Lines 122-157	
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	Page 4-5: Lines 95-109	
Bias	9	Describe any efforts to address potential sources of bias	Not Applicable	
Study size	10	Explain how the study size was arrived at	Not Applicable	

Continued on next page

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 5-6: Lines 122-157
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Page 7-8: Lines 159-179
		(b) Describe any methods used to examine subgroups and interactions	Not Applicable
		(c) Explain how missing data were addressed	Page 6: Lines 118-119
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed	Not Applicable
		<i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	
		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	Not Applicable
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: Lines 181-187
		(b) Give reasons for non-participation at each stage	Not Applicable
		(c) Consider use of a flow diagram	Not Applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 20: Table 1
		(b) Indicate number of participants with missing data for each variable of interest	Page 20: Lines 181-187
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	Page 20: Line 183-184
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	Page 20: Table 1
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	Page 20: Table 1
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	Page 20: 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 21-22: Table 2 & Table 3
		(b) Report category boundaries when continuous variables were categorized	Page 7: Lines 145-157
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not Applicable

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Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not Applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 9-10: Lines 221-229
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 12-13: Lines 291-311
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 10: Lines 239-252
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 12: Lines 291-295
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 14: Lines 324-326

*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.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.