

# BMJ Open Effects of changes in eating speed on obesity in patients with diabetes: a secondary analysis of longitudinal health check-up data

Yumi Hurst, Haruhisa Fukuda

**To cite:** Hurst Y, Fukuda H. Effects of changes in eating speed on obesity in patients with diabetes: a secondary analysis of longitudinal health check-up data. *BMJ Open* 2018;**8**:e019589. doi:10.1136/bmjopen-2017-019589

► Prepublication history for this paper is available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2017-019589>).

Received 14 September 2017

Revised 9 December 2017

Accepted 14 December 2017

## ABSTRACT

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

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

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

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

## INTRODUCTION

Excess body weight and obesity can lead to an increased risk of developing non-communicable diseases such as diabetes, cardiovascular disease and various forms of cancer.<sup>1-4</sup> Studies have reported that the regulation of body weight can be effective in lowering these

## Strengths and limitations of this study

- This is the first panel data analysis to verify the effects of changes in eating habits on obesity.
- Long-term large-scale longitudinal data were used.
- Lifestyle habits were self-assessed and may be vulnerable to reporting bias.
- The sample comprised relatively health-conscious individuals who voluntarily participated in health check-ups, and the findings may therefore have limited applicability to less health-conscious people.

health risks.<sup>1-4</sup> However, a 10-year longitudinal study of Japanese men aged 40-69 years found that the proportion of overweight and obese individuals had increased over the study period.<sup>5</sup> In addition, the Japanese government's Annual Health, Labour and Welfare Report 2014 noted that the prevalence of obesity continues to rise, with a substantially higher prevalence among men in 2012 than in 1982.<sup>6</sup> The report also revealed that obesity prevalence exceeded 30% in men in their 40s and 50s. These figures suggest that current obesity prevention efforts in Japan may be inadequate. The fundamental cause of excess weight gain is the failure to ensure a balance between energy intake and energy expenditure.<sup>1</sup> However, recent studies have reported that excess weight gain and metabolic syndrome are affected by energy intake, and are influenced by other factors such as eating speed, eating frequency and other lifestyle habits.<sup>7-10</sup> In addition to emphasising the importance of balancing energy intake and expenditure, these other factors represent possible targets for obesity prevention measures.

In response to the rising prevalence of obesity, Japan's Ministry of Health, Labour and Welfare introduced a nationwide health screening programme (Standard Health Check-up and Counselling Guidance



Department of Health Care Administration and Management, Kyushu University Graduate School of Medical Sciences, Fukuoka, Japan

### Correspondence to

Dr Haruhisa Fukuda; [h\\_fukuda@hcam.med.kyushu-u.ac.jp](mailto:h_fukuda@hcam.med.kyushu-u.ac.jp)

Programme) to detect risk factors for obesity and metabolic syndrome.<sup>11 12</sup> Under this programme, insurers conduct 'specific health check-ups' aimed at insurance enrollees aged 40 years or older. However, participation in these check-ups is not mandatory.

Although many studies have addressed the associations between lifestyle habits and obesity, few have examined the causal effects of changes in lifestyle habits on obesity. In addition, studies from Japan have shown that the number of persons with type 2 diabetes has increased with increasing body mass index (BMI),<sup>13</sup> and that BMI is an independent risk factor for this condition.<sup>14</sup> This study focuses on persons with type 2 diabetes as they are likely to benefit directly from health improvements arising from the alleviation of obesity. The main objective of this study was to use panel data to analyse the effects of changes in eating speed and other lifestyle habits on obesity in patients with type 2 diabetes. For this analysis, we hypothesised that slower eating speeds would reduce obesity.

## METHODS

### Data source

This study used a commercial database obtained from the Japan Medical Data Center (JMDC), a for-profit organisation that collects, curates and distributes health-related data. The database comprised insurance claims data and health check-up data for insurance enrollees and their dependents that were collected through JMDC's contracts with several health insurance societies in Japan. The claims data included information on the dates of consultations and treatments, sex, age, diagnoses, specific treatments and healthcare expenditure. The health check-up data included the dates of check-ups, BMI, waist circumference, blood pressure and the results of blood chemical analysis, liver function test, blood glucose test and urinalysis. The health check-up data also included the subjects' responses to several questions regarding lifestyle factors, such as eating habits, alcohol consumption, tobacco use and sleeping habits.<sup>12</sup> The claims data and health check-up data were linked at the individual subject level for analysis.

### Study design

We first identified subjects with at least one recorded diagnosis of type 2 diabetes in their claims data from January 2005 to June 2013 using the corresponding International Classification of Diseases, 10th revision codes (E10–E14). Both the claims data and health check-up data from this study period were used in the analysis. From the claims data, we obtained information on subject sex, age, and the starting date of antidiabetic medication. The claims data were linked with the health check-up data at the patient-month level to generate panel data. We excluded subjects with missing data for BMI and lifestyle habits. The results from each subject's first specific health check-up during the study period were used as the baseline values.

## Outcomes

The primary outcome of this study was obesity status. According to WHO's criteria, a BMI of 25 or more indicates that a person is overweight, and a BMI of 30 or more indicates obesity. However, it has been proposed that these BMI cut-off points should be lower for Asian populations.<sup>15</sup> The Japan Society for the Study of Obesity has recommended that obesity be defined by a BMI of 25 or more for the Japanese population.<sup>16</sup> In accordance with this recommendation, our study uses a BMI cut-off point of 25 to identify obese individuals. The secondary outcomes of this study were BMI and waist circumference, which were analysed as continuous variables.

## Exposure variables

The exposure variables consisted of the seven question items regarding lifestyle habits. The main exposure of interest was eating speed. The other items were eating dinner within 2 hours before sleeping for three times or more per week, snacking after dinner for three times or more per week, skipping breakfast three times or more per week, alcohol consumption frequency, sleep adequacy and habitual smoking. These variables were analysed as categorical variables based on the response options. Eating speed was analysed as three categories ('fast', 'normal' and 'slow'). Eating dinner within 2 hours before sleeping for three times or more per week, snacking after dinner for three times or more per week, skipping breakfast three times or more per week, adequate sleep, and habitual smoking were analysed as two categories ('yes' and 'no'). Alcohol consumption frequency was analysed as three categories ('every day', 'occasionally' and 'rarely or never').

## Covariates

The covariates were selected from factors thought to influence lifestyle habits and weight management. These included the use of antidiabetic medication (as an indicator of diabetes that requires pharmacological treatment), age, as well as obesity status and BMI in the previous check-up. The use or non-use of antidiabetic medication was determined based on whether the patient had been administered antidiabetic medication at the time of each health check-up. This variable was analysed as two categories ('yes' and 'no'). In addition to human insulin preparations and insulin analogues, antidiabetic medications also included sulfonylureas, biguanide derivatives, glitazones,  $\alpha$ -glucosidase inhibitors, glinides, dipeptidyl peptidase-4 (DPP-4) inhibitors and glucagon-like peptide (GLP)-1 receptor agonists. Age and BMI in the previous check-up were analysed as continuous variables. Obesity status in the previous check-up was analysed as two categories ('yes' for BMI  $\geq 25$  and 'no' for BMI  $< 25$ ).

## Statistical analysis

The subject baseline characteristics of sex, age, BMI, obesity status, waist circumference and lifestyle habits were compared among the three eating speed categories

using the  $\chi^2$  test or one-way analysis of variance. Patient-level panel data were generated using repeated estimates from multiple health check-ups. This study used longitudinal data from annual health check-ups collected over approximately 6 years. The application of panel data enables the estimation of changes in the dependent variables that result from changes in eating speed (eg, fast to fast, fast to normal, fast to slow and so on) in individual subjects.

We first constructed a generalised estimating equation model to elucidate the effects of changes in eating speed on obesity. The exposure variables were the seven lifestyle habit items, and the covariates were the use of antidiabetic medication, age, sex and obesity status in the previous check-up.

In order to estimate the influence of changes in eating speed on BMI and waist circumference, we used fixed-effects models with these factors as the dependent variables. The exposure variables were the seven lifestyle habit items, and the covariates were the use of antidiabetic medication, age and BMI or waist circumference in the previous check-up. Sex and other covariates that remained unchanged throughout the observation period were adjusted as fixed effects. The Hausman test was employed for model selection; the P value was below 0.001, which confirmed that the use of the fixed-effects model was appropriate.

All statistical analyses were conducted using Stata V.13.1 (Stata Corp, College Station, Texas, USA). Statistical significance was set at  $P < 0.05$ .

## RESULTS

We identified 92363 individuals from 303361 person-months who had been diagnosed with type 2 diabetes and had health check-up data for the period between January 2005 and June 2013. After excluding cases with missing data in BMI and the lifestyle habit items, the sample for analysis comprised 59717 individuals from 129978 person-months. The claims data and health check-up data that could be linked for analysis covered the period from February 2008 to June 2013.

The distribution of baseline characteristics according to eating speed is presented in table 1. The slow-eating group had a significantly higher proportion of women (44.4%), lower mean BMI ( $22.3 \pm 4.0$ ), lower proportion of obese individuals (21.5%), smaller mean waist circumference ( $80.1 \pm 10.6$  cm), lower alcohol consumption frequency (every day: 22.8%; occasionally: 27.5%; rarely or never: 49.7%) and lower proportion of habitual smokers (27.3%) when compared with the other two groups (all:  $P < 0.001$ ). In contrast, the fast-eating group had a significantly lower proportion of women (27.3%,  $P < 0.001$ ), but a significantly higher mean BMI ( $25.0 \pm 4.4$ ,  $P < 0.001$ ), higher proportion of obese individuals (44.8%,  $P < 0.001$ ) and larger mean waist circumference ( $86.8 \pm 11.1$  cm,  $P < 0.001$ ).

The mean number (and SD) of health check-ups among the 59171 subjects used in the panel data analysis was 1.9 (1.1). The distribution of subjects (and percentage of all subjects) according to the number of health check-ups undergone during the study period was as follows: 21805

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

	Eating speed			P value
	Fast (n=22070)	Normal (n=33455)	Slow (n=4192)	
Women	6023 (27.3%)	12213 (36.5%)	1861 (44.4%)	<0.001*
Age	46.6 (10.4)	48.1 (10.6)	46.5 (11.7)	<0.001†
Use of antidiabetic medications	13648 (61.8%)	20074 (60.0%)	2525 (60.2%)	<0.001*
BMI, kg/m <sup>2</sup>	25.0 (4.4)	23.4 (3.9)	22.3 (4.0)	<0.001†
Obese (BMI $\geq 25$ )	9884 (44.8%)	9886 (29.6%)	901 (21.5%)	<0.001*
Waist circumference (cm)	86.8 (11.1)	82.8 (10.4)	80.1 (10.6)	<0.001†
Eating dinner within 2 hours before sleeping $\geq 3$ times per week	9546 (43.3%)	11161 (33.4%)	1541 (36.8%)	<0.001*
Snacking after dinner $\geq 3$ times per week	4247 (19.2%)	4851 (14.5%)	809 (19.3%)	<0.001*
Skipping breakfast $\geq 3$ times per week	4599 (20.8%)	5542 (16.6%)	794 (18.9%)	<0.001*
Alcohol consumption				
Every day	5695 (25.8%)	8810 (26.3%)	955 (22.8%)	<0.001*
Occasionally	7233 (32.8%)	10398 (31.1%)	1152 (27.5%)	<0.001*
Rarely or never	9142 (41.4%)	14247 (42.6%)	2085 (49.7%)	<0.001*
Inadequate sleep	11236 (50.9%)	15018 (44.9%)	1954 (46.6%)	<0.001*
Habitual smoker	7140 (32.4%)	10240 (30.6%)	1146 (27.3%)	<0.001*

Values for number of check-ups, age and BMI are presented as mean (SD). All other values are presented as number of subjects (proportion of each eating-speed group).

\* $\chi^2$  test.

†One-way analysis of variance.

BMI, body mass index.

**Table 2** Patterns of changes in eating speed during the intermediate and final phases of 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)
NA	Fast*	5839 (9.8)	1322 (2.2)	30 (0.1)
NA	Normal*	1155 (1.9)	7749 (13.0)	350 (0.6)
NA	Slow*	32 (0.1)	417 (0.7)	800 (1.3)
NA	NA†	7654 (12.8)	12 693 (21.3)	1458 (2.4)

Some subjects may report different eating speeds throughout their check-ups during the study period. In addition, subjects who underwent four to six check-ups may have different reported eating speeds during their intermediate phase (second to fifth check-ups); in these subjects, the eating speeds during the intermediate phase were categorised in the following order of priority: slow, normal and fast. For example, a subject with both slow and fast eating speeds reported in the second to fifth check-ups would be reflected as having a slow eating speed during the intermediate phase.

\*Subjects with only two eating speed measurements during the study period.

†Subjects with only one eating speed measurement during the study period.

NA, not applicable.

subjects (36.5%) with one check-up, 17 694 (29.6%) subjects with two check-ups, 12 075 (20.2%) subjects with three check-ups, 4524 (7.6%) subjects with four check-ups, 3248 (5.4%) subjects with five check-ups and 371 (0.6%) subjects with six check-ups. **Table 2** shows the changes in eating speed across these check-ups according to the different baseline eating speeds. Approximately half (51.9%) of the subjects exhibited changes in eating speed from baseline during the study period. The results showed that 171 subjects (0.29%) changed from being fast eaters to slow eaters, whereas 92 subjects (0.15%) changed from being slow eaters to fast eaters.

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

The estimated coefficients of the various determinants of changes in BMI are presented in **table 4**. Eating speed

(normal:  $P<0.001$ ; slow:  $P<0.001$ ), eating dinner within 2 hours before sleeping for three times or more per week ( $P<0.001$ ), snacking after dinner for three times or more per week ( $P<0.001$ ), BMI in the previous check-up ( $P<0.001$ ), alcohol consumption frequency (occasionally:  $P<0.001$ ; rarely or never:  $P=0.002$ ) and age ( $P=0.008$ ) were significantly associated with changes in BMI. With the exception of inadequate sleep, habitual smoking, age and BMI in the previous check-up, the coefficients of all the other factors were negative. This indicated that eating slower, not eating dinner within 2 hours before sleeping, not snacking after dinner and drinking infrequently were associated with reductions in BMI. Skipping breakfast three times or more per week, habitual smoking and the use of antidiabetic medication were not significantly associated with BMI.

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

## DISCUSSION

This study analysed Japanese men and women who had undergone specific health check-ups regardless of obesity status. Possible lifestyle-related determinants of obesity were identified using questionnaire items from the Standard Health Check-up and Counselling Guidance



**Table 3** Estimated ORs of the determinants of obesity derived from the generalised estimating equation model

	OR	95% CI	P value
<b>Eating speed</b>			
Fast	Reference		
Normal	0.71	0.68 to 0.75	<0.001
Slow	0.58	0.54 to 0.63	<0.001
<b>Eating dinner within 2 hours before sleeping <math>\geq 3</math> times per week</b>			
Yes	Reference		
No	0.90	0.86 to 0.94	<0.001
<b>Snacking after dinner <math>\geq 3</math> times per week</b>			
Yes	Reference		
No	0.85	0.80 to 0.90	<0.001
<b>Skipping breakfast <math>\geq 3</math> times per week</b>			
Yes	Reference		
No	0.92	0.87 to 0.97	0.004
<b>Alcohol consumption</b>			
Every day	Reference		
Occasionally	1.18	1.12 to 1.25	<0.001
Rarely or never	1.22	1.16 to 1.29	<0.001
<b>Inadequate sleep</b>			
Yes	Reference		
No	0.94	0.90 to 0.98	0.007
<b>Habitual smoker</b>			
Yes	Reference		
No	1.10	1.05 to 1.15	<0.001
<b>Use of antidiabetic medication</b>			
No	Reference		
Yes	1.02	0.98 to 1.07	0.293
Age	1.00	1.00 to 1.00	0.076
Female	0.66	0.63 to 0.69	<0.001
<b>Obesity status in the previous check-up</b>			
Not obese	Reference		
Obese	164.79	156.15 to 173.91	<0.001

Programme.<sup>12</sup> We examined 6-year panel data to determine how changes in eating speed and other lifestyle habits affect obesity and BMI. The main results indicated that decreases in eating speeds can lead to reductions in obesity and BMI after controlling for the covariates. In addition, the study found that the cessation of eating after dinner or within 2 hours before sleeping would also have a similar effect on reducing excess body weight.

A strength of this study is the usage of large-scale panel data from approximately 60 000 patients with diabetes spanning a 6-year observation period. The use of panel data increases the accuracy of estimates when compared with conventional cross-sectional and time series data.<sup>17</sup> Panel data also enable adjustments of the unobservable

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

	Coefficient	95% CI	P value
<b>Eating speed</b>			
Fast	Reference		
Normal	-0.07	-0.10 to 0.05	<0.001
Slow	-0.11	-0.15 to 0.06	<0.001
<b>Eating dinner within 2 hours before sleeping <math>\geq 3</math> times per week</b>			
Yes	Reference		
No	-0.06	-0.08 to 0.04	<0.001
<b>Snacking after dinner <math>\geq 3</math> times per week</b>			
Yes	Reference		
No	-0.08	-0.11 to 0.06	<0.001
<b>Skipping breakfast <math>\geq 3</math> times per week</b>			
Yes	Reference		
No	0.00	-0.03 to 0.04	0.829
<b>Alcohol consumption</b>			
Every day	Reference		
Occasionally	-0.10	-0.13 to 0.06	<0.001
Rarely or never	-0.18	-0.22 to 0.13	<0.001
<b>Inadequate sleep</b>			
Yes	Reference		
No	0.03	0.01 to 0.05	0.001
<b>Habitual smoker</b>			
Yes	Reference		
No	0.23	0.20 to 0.27	0.363
<b>Use of antidiabetic medication</b>			
No	Reference		
Yes	-0.12	-0.14 to 0.10	0.069
Age	0.08	0.07 to 0.10	0.008
BMI in the previous check-up	0.09	0.07 to 0.10	<0.001

BMI, body mass index.

differences between study subpopulations, thereby facilitating analyses of the effects of behavioural changes in subjects. Another strength of this study is the incorporation of data on lifestyle habits, such as eating, sleeping and smoking. By analysing the associations between these habits and obesity, our study was able to quantify the possible effects of changes in these habits on obesity.

The major finding of this study is that changes in eating speed can affect obesity, BMI and waist circumference. The control of eating speed may therefore be a possible means of regulating body weight and preventing obesity, which in turn reduces the risk of developing non-communicable diseases. Eating quickly is associated with impaired glucose tolerance and insulin resistance,<sup>18 19</sup> and is a known risk factor for diabetes through increases in body weight.<sup>20</sup> Other studies have also reported associations between eating quickly and increased BMI, indicating that eating speed is a contributing factor for

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

	Coefficient	95% CI	P value
<b>Eating speed</b>			
Fast	Reference		
Normal	-0.21	-0.30 to 0.12	<0.001
Slow	-0.41	-0.59 to 0.22	<0.001
<b>Eating dinner within 2 hours before sleeping <math>\geq 3</math> times per week</b>			
Yes	Reference		
No	-0.12	-0.20 to 0.04	0.003
<b>Snacking after dinner <math>\geq 3</math> times per week</b>			
Yes	Reference		
No	-0.2	-0.29 to 0.11	<0.001
<b>Skipping breakfast <math>\geq 3</math> times per week</b>			
Yes	Reference		
No	0.03	-0.11 to 0.16	0.674
<b>Alcohol consumption</b>			
Every day	Reference		
Occasionally	-0.34	-0.47 to 0.20	<0.001
Rarely or never	-0.47	-0.65 to 0.29	<0.001
<b>Inadequate sleep</b>			
Yes	Reference		
No	0.07	0.00 to 0.14	0.053
<b>Habitual smoker</b>			
Yes	Reference		
No	0.8	0.66 to 0.95	<0.001
<b>Use of antidiabetic medication</b>			
No	Reference		
Yes	-0.32	-0.41 to 0.23	<0.001
Age	0.27	0.24 to 0.30	<0.001
Waist circumference in the previous check-up	-0.11	-0.12 to 0.10	<0.001

obesity.<sup>7 8 21–26</sup> A possible reason for this association is that fast eaters may continue to eat until they feel full despite having already consumed an adequate amount of calories, and the combined effect of eating quickly and overeating may contribute to weight gain.<sup>27</sup> In contrast, eating slowly may help to increase feelings of satiety before an excessive amount of food is ingested.<sup>28–30</sup> A prospective study of schoolgirls found that the reduction of eating speed was able to suppress weight gain and prevent obesity.<sup>31</sup> The findings of these studies are consistent with those of our analysis.

In addition to BMI-based definitions of obesity, waist circumference-based definitions of abdominal obesity have also become increasingly important in recent years. Cerhan *et al* proposed that assessments of waist circumference should accompany assessments of BMI.<sup>32</sup> As a supplementary analysis, we employed a fixed-effects model to

examine the effects of changes in eating speed on waist circumference in our subjects. The results showed that when compared with fast eaters, normal-speed eaters and slow eaters had reductions in waist circumference of 0.21 cm and 0.41 cm, respectively ( $P < 0.001$ ). These results support our findings of the effects of changes in eating speed on obesity.

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

The association between daily alcohol consumption and obesity remains controversial. While several studies have identified this lifestyle habit as a risk factor of metabolic syndrome,<sup>7 35</sup> others have reported an inverse association between the frequency of alcohol consumption (given the same quantities of alcohol) and obesity.<sup>36 37</sup> In our study, the frequency of alcohol consumption was found to be inversely associated with obesity, but positively associated with BMI and waist circumference. In order to clarify this apparent disparity, further analyses of alcohol consumption should be conducted with consideration to the overall quantities of alcohol consumed.

Studies have also found associations between short sleep durations and BMI increases, and that poor-quality sleep is associated with metabolic syndrome.<sup>38–40</sup> Our analysis produced contradictory results in that a change from adequate sleep to inadequate sleep would reduce BMI but increase obesity progression. Moreover, we did not detect any significant association between sleep and waist circumference. A recent study has shown that unstable sleep patterns may increase the quantity of food intake,<sup>41</sup> and our findings therefore require further investigation. The lack of association between habitual smoking and BMI or metabolic syndrome has been reported in previous studies,<sup>7 42</sup> which corroborates our findings.

This study has several limitations that should be considered. First, this study used health check-up data from health insurance societies. As a result, the data may not have included a large proportion of the insurance enrollees' dependents. In particular, there was a relatively small proportion of older adults in our study population. The results may therefore lack generalisability to other subpopulations. Second, eating speed and the other

lifestyle habits were self-assessed, and may therefore be vulnerable to reporting bias. However, while the differences in perceptions of eating and sleeping habits in standardised questionnaires have been described,<sup>43</sup> Sasaki *et al* reported that there was no difference between the eating speeds assessed by study subjects or by friends of the subjects.<sup>25</sup> In addition, our findings are consistent with those of a previous study that used objective measures of eating speed and found that slower eating speeds were associated with greater weight loss.<sup>30</sup> Third, we did not include an analysis of physical exercise and energy intake, which may be potential confounders. Nevertheless, a previous analysis has reported that eating speed was associated with obesity regardless of the level of physical activity.<sup>26</sup> Other studies have also reported similar associations between eating speed and BMI given similar overall food intake, which corroborates our findings.<sup>24 25</sup> Therefore, these two factors are unlikely to be confounders in this study despite their association with BMI. Finally, the sample comprised relatively health-conscious individuals who voluntarily participated in health check-ups. The findings may therefore have limited applicability to less health-conscious people.

Many studies have shown that eating habits are associated with BMI and weight gain.<sup>7 8 18–31</sup> However, this study used panel data to show that changes in eating habits have a strong relationship with obesity, BMI and waist circumference. These findings indicate that weight loss can be supported through the reduction of eating speed, the cessation of eating dinner within 2 hours before sleeping, the cessation of snacking after dinner and consistently having breakfast.

## CONCLUSIONS

Changes in eating habits can affect obesity, BMI and waist circumference. Interventions aimed at altering eating habits, such as education initiatives and programme to reduce eating speed, may be useful in preventing obesity and reducing the risk of non-communicable diseases.

**Contributors** YH contributed to data analysis and interpretation, and drafting of the manuscript. HF contributed to the study concept, design and interpretation and drafting of the manuscript.

**Funding** This work was supported by Grant-in-Aid for Health Sciences Research by the Ministry of Health, Labour and Welfare of Japan (Grant Number H29-Seisaku-Shitei-010).

**Competing interests** None declared.

**Patient consent** Not required.

**Ethics approval** This study was approved by the ethics committee of the Japan Medical Data Center (No. 18-09-2014).

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data sharing statement** No additional data are available.

**Open Access** This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

© Article author(s) (or their employer(s) unless otherwise stated in the text of the article) 2018. All rights reserved. No commercial use is permitted unless otherwise expressly granted.

## REFERENCES

- World Health Organization. Media centre, obesity and overweight. <http://www.who.int/mediacentre/factsheets/fs311/en/> (accessed 19 Aug 2017).
- Oh SW, Shin SA, Yun YH, *et al*. Cut-off point of BMI and obesity-related comorbidities and mortality in middle-aged Koreans. *Obes Res* 2004;12:2031–40.
- Yoon KH, Lee JH, Kim JW, *et al*. Epidemic obesity and type 2 diabetes in Asia. *Lancet* 2006;368:1681–8.
- Huxley R, Mendis S, Zheleznyakov E, *et al*. Body mass index, waist circumference and waist:hip ratio as predictors of cardiovascular risk—a review of the literature. *Eur J Clin Nutr* 2010;64:16–22.
- Matsushita Y, Takahashi Y, Mizoue T, *et al*. Overweight and obesity trends among Japanese adults: a 10-year follow-up of the JPHC Study. *Int J Obes* 2008;32:1861–7.
- Ministry of Health, Labour and Welfare. Annual Health, Labour and Welfare Report 2013–2014. Toward the Realization of a Society of Health and Longevity: The First Year of Health and Prevention. <http://www.mhlw.go.jp/wp/hakusyo/kousei/14/backdata/> (accessed 19 Aug 2017).
- Ashizawa E, Katano S, Harada A, *et al*. Exploring the link between standard lifestyle questionnaires administered during specific medical check-ups and incidence of metabolic syndrome in Chiba Prefecture. *Nihon Koshu Eisei Zasshi* 2014;61:176–85.
- Zhu B, Haruyama Y, Muto T, *et al*. Association between eating speed and metabolic syndrome in a three-year population-based cohort study. *J Epidemiol* 2015;25:332–6.
- Horikawa C, Kodama S, Yachi Y, *et al*. Skipping breakfast and prevalence of overweight and obesity in Asian and Pacific regions: a meta-analysis. *Prev Med* 2011;53:260–7.
- Ferrie JE, Kivimäki M, Akbaraly TN, *et al*. Change in sleep duration and type 2 diabetes: the whitehall II study. *Diabetes Care* 2015;38:1467–72.
- Tamura T, Kimura Y. Specific health checkups in Japan: the present situation analyzed using 5-year statistics and the future. *Biomed Eng Lett* 2015;5:22–8.
- Health Service Bureau, the Ministry of Health, Labour and Welfare. Standard Health Checkup and Counseling Guidance Program (Revised Version). [http://www.mhlw.go.jp/stf/seisakunitsuite/bunya/kenkou\\_iryuu/kenkou/seikatsu/](http://www.mhlw.go.jp/stf/seisakunitsuite/bunya/kenkou_iryuu/kenkou/seikatsu/) (accessed 19 Aug 2017).
- Yoshiike N, Nishi N, Matsushima S, *et al*. Relationship between the severity of obesity based on body mass index and the risk factors for diabetes, hypertension, and hyperglycemia: a multicenter epidemiological study. *Obesity Res* 2000;6:4–17. [in Japanese].
- Waki K, Noda M, Sasaki S, *et al*. Alcohol consumption and other risk factors for self-reported diabetes among middle-aged Japanese: a population-based prospective study in the JPHC study cohort I. *Diabet Med* 2005;22:323–31.
- WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet* 2004;363:157–63.
- Saito Y, Shirai K, Nakamura T, *et al*. Diagnostic criteria for obesity 2011. *Obesity Res* 2011;7:s1–78. [in Japanese].
- Kitamura Y. Meanings of panel data and its use. *Jpn J Labour Stud* 2006;55:16–16. [in Japanese].
- Totsuka K, Maeno T, Saito K, *et al*. Self-reported fast eating is a potent predictor of development of impaired glucose tolerance in Japanese men and women: Tsukuba Medical Center Study. *Diabetes Res Clin Pract* 2011;94:e72–4.
- Otsuka R, Tamakoshi K, Yatsuya H, *et al*. Eating fast leads to insulin resistance: findings in middle-aged Japanese men and women. *Prev Med* 2008;46:154–9.
- Sakurai M, Nakamura K, Miura K, *et al*. Self-reported speed of eating and 7-year risk of type 2 diabetes mellitus in middle-aged Japanese men. *Metabolism* 2012;61:1566–71.
- Yamane M, Ekuni D, Mizutani S, *et al*. Relationships between eating quickly and weight gain in Japanese university students: a longitudinal study. *Obesity* 2014;22:2262–6.
- Tanihara S, Imatoh T, Miyazaki M, *et al*. Retrospective longitudinal study on the relationship between 8-year weight change and current eating speed. *Appetite* 2011;57:179–83.
- Oya J, Nakagami T, Sasaki S, *et al*. Characteristics of nutritional intake and exercise habits according to classifications of the Standard Health Checkup and Counseling Guidance Program: an analysis of Kurihara Lifestyle Cohort Study data. *J Clin Nutr Metab* 2011;14:25–32. [in Japanese].

24. Otsuka R, Tamakoshi K, Yatsuya H, *et al.* Eating fast leads to obesity: findings based on self-administered questionnaires among middle-aged Japanese men and women. *J Epidemiol* 2006;16:117–24.
25. Sasaki S, Katagiri A, Tsuji T, *et al.* Self-reported rate of eating correlates with body mass index in 18-y-old Japanese women. *Int J Obes Relat Metab Disord* 2003;27:1405–10.
26. Momose Y, Une H, Hayashi M, *et al.* Habit of eating quickly is independently related with overweight among Japanese rural residents aged 40–79 years. *J Jpn Assoc Rural Med* 2010;58:533–40. [in Japanese].
27. Maruyama K, Sato S, Ohira T, *et al.* The joint impact on being overweight of self reported behaviours of eating quickly and eating until full: cross sectional survey. *BMJ* 2008;337:a2002.
28. Andrade AM, Greene GW, Melanson KJ. Eating slowly led to decreases in energy intake within meals in healthy women. *J Am Diet Assoc* 2008;108:1186–91.
29. Martin CK, Anton SD, Walden H, *et al.* Slower eating rate reduces the food intake of men, but not women: implications for behavioral weight control. *Behav Res Ther* 2007;45:2349–59.
30. Spiegel TA, Wadden TA, Foster GD. Objective measurement of eating rate during behavioral treatment of obesity. *Behav Ther* 1991;22:61–7.
31. Ochiai H, Shirasawa T, Ohtsu T, *et al.* The impact of eating quickly on anthropometric variables among schoolgirls: a prospective cohort study in Japan. *Eur J Public Health* 2014;24:691–5.
32. Cerhan JR, Moore SC, Jacobs EJ, *et al.* A pooled analysis of waist circumference and mortality in 650,000 adults. *Mayo Clin Proc* 2014;89:335–45.
33. Odegaard AO, Jacobs DR, Steffen LM, *et al.* Breakfast frequency and development of metabolic risk. *Diabetes Care* 2013;36:3100–6.
34. Smith KJ, Gall SL, McNaughton SA, *et al.* Skipping breakfast: longitudinal associations with cardiometabolic risk factors in the Childhood Determinants of Adult Health Study. *Am J Clin Nutr* 2010;92:1316–25.
35. Dorn JM, Hovey K, Muti P, *et al.* Alcohol drinking patterns differentially affect central adiposity as measured by abdominal height in women and men. *J Nutr* 2003;133:2655–62.
36. Tolstrup JS, Halkjaer J, Heitmann BL, *et al.* Alcohol drinking frequency in relation to subsequent changes in waist circumference. *Am J Clin Nutr* 2008;87:957–63.
37. Tolstrup JS, Heitmann BL, Tjønneland AM, *et al.* The relation between drinking pattern and body mass index and waist and hip circumference. *Int J Obes* 2005;29:490–7.
38. Lee J, Choi YS, Jeong YJ, *et al.* Poor-quality sleep is associated with metabolic syndrome in Korean adults. *Tohoku J Exp Med* 2013;231:281–91.
39. Nishiura C, Hashimoto H. A 4-year study of the association between short sleep duration and change in body mass index in Japanese male workers. *J Epidemiol* 2010;20:385–90.
40. Taheri S, Lin L, Austin D, *et al.* Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. *PLoS Med* 2004;1:e62.
41. Lundahl A, Nelson TD. Sleep and food intake: a multisystem review of mechanisms in children and adults. *J Health Psychol* 2015;20:794–805.
42. Sogabe N, Maruyama R, Sato K, *et al.* [Relationships between smoking and eating habits or behavior in male students]. *Nihon Koshu Eisei Zasshi* 2008;55:30–6. [in Japanese].
43. Yamauchi T, Takaki M, Tonai M. Images and recognition about “eating quickly”. *J Jpn Soc Health Care Manag* 2003;4:311–8. [in Japanese].