BMJ Open

The effects of changes in eating speed on obesity

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-019589
Article Type:	Research
Date Submitted by the Author:	14-Sep-2017
Complete List of Authors:	Hurst, Yumi; Kyushu University, Department of Health Care Administration and Management Fukuda , H ; Kyushu University, Department of Health Care Administration and Management
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology
Keywords:	PUBLIC HEALTH, obesity, Body mass index, eating habits, health checkups

The effects of changes in eating speed on obesity

Hurst Y, Fukuda H.

Department of Health Care Administration and Management,

Kyushu University Graduate School of Medical Sciences

3-1-1, Maidashi, Higashi-ku, Fukuoka, 812-8582, Japan

Corresponding Author

Haruhisa Fukuda, MPH, PhD

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

3-1-1 Maidashi Higashi-ku Fukuoka 812-8582, Japan

Phone: +81-92-642-6956 Fax: +81-92-642-6961

Email address: h_fukuda@hcam.med.kyushu-u.ac.jp

Abstract

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

Methods Patient-level panel data from 2008 to 2013 were generated using commercially available insurance claims data and health checkup 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 checkups. 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 generalized estimating equation model and fixed-effects model were used to examine the effects of these habits on obesity and BMI, respectively.

Results The generalized estimating equation model showed that eating slower inhibited the development of obesity. The odds ratios for slow (0.56) and normal-speed eaters (0.70) indicated that these groups were less likely to be obese than fast eaters ($P < 0.001$). Similarly, the fixed-effects model showed that eating slower reduced BMIs. Relative to fast eaters, the coefficients 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 and BMI. Interventions aimed at reducing eating speed may be effective in preventing obesity and lowering the associated health risks.

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

Strengths and limitations of this study

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

2. The large-scale study sample consisted of approximately 60,000 young to middle-aged subjects.

3. The analysis also examined alcohol consumption, sleep adequacy, and tobacco consumption.

4. Lifestyle habits were self-assessed and may therefore be vulnerable to reporting bias.

5. The sample comprised relatively health-conscious individuals who voluntarily participated in health checkups, and the findings may therefore have limited applicability to less health-conscious people.

Funding Statement:

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 Statement:

No potential conflicts of interest relevant to this article were reported.

Author Contribusions:

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.

Introduction

Excess body weight and obesity can lead to an increased risk of developing noncommunicable diseases such as cardiovascular disease, diabetes, and various forms of cancer.[1-4] Studies have reported that the regulation of body weight can be effective in lowering these health risks.[1-4] However, a 10-year longitudinal study of Japanese men aged 40 to 69 years found that the proportion of overweight and obese individuals had increased over the study period.[5] 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.[6] 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.[1] However, recent studies have reported that excess weight gain and metabolic syndrome are affected not only by energy intake, but are also influenced by other factors such as eating speed, eating frequency, and other lifestyle habits.[7-10] In addition to emphasizing 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 program (Standard Health Checkup and Counseling Guidance Program) to detect risk factors for obesity and metabolic syndrome.[11,12] Under this program, insurers conduct "specific health checkups" aimed at insurance enrollees aged 40 years or older. However, participation in these checkups 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. The main objective of this study was to utilize panel data to analyze the effects of changes in eating speed and other lifestyle habits on obesity.

Methods

Data source

This study used a commercial database obtained from the Japan Medical Data Center (JMDC), a for-profit organization that collects, curates, and distributes health-related data. The database comprised insurance claims data and health checkup data for insurance enrollees and their dependents that were collected through JMDC's contracts with several health insurance societies. The claims data included information on the dates of consultations and treatments, sex, age, diagnoses, specific treatments, and healthcare expenditure. The health checkup data included the dates of checkups, body mass index (BMI), blood pressure, and the results of blood chemical analysis, liver function test, blood glucose test, and urinalysis. The health checkup data also included the subjects' responses to several questions regarding lifestyle factors, such as eating habits, alcohol consumption, tobacco use, and sleeping habits.[12] The claims data and health checkup 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. Both the claims data and health checkup 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 anti-diabetic medication. The claims data were linked with the health checkup 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 checkup during the study period were used as the baseline values.

Outcomes

The primary outcome of this study was obesity status. According to the World Health Organization'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.[13] 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.[14] In accordance with this recommendation, our study uses a BMI cut-off point of 25 to identify obese individuals. The secondary outcome of this study was BMI, which was analyzed as a continuous variable.

Exposure variables

The exposure variables consisted of the 7 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 3 times or more per week, snacking after dinner for 3 times or more per week, skipping breakfast 3 times or more per week, alcohol consumption frequency, sleep adequacy, and habitual smoking. These variables were analyzed as categorical variables based on the response options. Eating speed was analyzed as 3 categories ("fast", "normal", and "slow"). Eating dinner within 2 hours before sleeping for 3 times or more per week, snacking after dinner for 3 times or more per week, skipping breakfast 3 times or more per week, adequate sleep, and habitual smoking were analyzed as 2 categories ("yes" and "no"). Alcohol consumption frequency was analyzed as 3 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 anti-diabetic medication (as an indicator of diabetes that requires pharmacologic treatment), age, as well as obesity status and BMI in the previous checkup. The use or non-use of anti-diabetic medication was determined based on whether the patient had been administered anti-diabetic medication at the time of each health checkup. This variable was analyzed as 2 categories (“yes” and “no”). In addition to human insulin preparations and insulin analogs, anti-diabetic medications also included sulfonylureas, biguanide derivatives, glitazones, α-glucosidase inhibitors, glinides, DPP-4 inhibitors, and GLP-1 receptor agonists. Age and BMI in the previous checkup were analyzed as continuous variables. Obesity status in the previous checkup was analyzed as 2 categories (“yes” for BMI ≥25 and “no” for BMI <25).

Statistical analysis

The subject baseline characteristics of sex, age, BMI, obesity status, and lifestyle habits were compared among the 3 eating speed categories using the χ^2 test or one-way analysis of variance. Patient-level panel data were generated using repeated estimates from multiple health checkups. We constructed a generalized estimating equation model to elucidate the effects of changes in eating speed on obesity. The dependent variable was obesity status. The exposure variables were the 7 lifestyle habit items, and the covariates were the use of anti-diabetic medication, age, and obesity status in the previous checkup.

In order to estimate the influence of changes in eating speed on BMI, we utilized a fixed-effects model where the dependent variable was BMI. The exposure variables were the 7 lifestyle habit items, and the covariates were the use of anti-diabetic medication, age, and BMI in the previous checkup. The Hausman test was employed for model selection.

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

Results

We identified 92,363 individuals from 303,361 person-months who had been diagnosed with type 2 diabetes and had health checkup 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 59,717 individuals from 129,978 person-months. The claims data and health checkup 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±4.0), lower proportion of obese individuals (21.5%), 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 2 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±4.4, $P < 0.001$) and higher proportion of obese individuals (44.8%, $P < 0.001$).

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

The estimated coefficients of the various determinants of changes in BMI are presented in Table 3. Eating speed (normal: $P < 0.001$; slow: $P < 0.001$), eating dinner within 2 hours before sleeping for 3 times or more per week ($P < 0.001$), snacking after dinner for 3 times or more per week ($P < 0.001$), BMI in the previous checkup ($P < 0.001$), alcohol consumption frequency (occasionally: $P < 0.001$; rarely or never: $P = 0.002$), sleep adequacy ($P < 0.001$), and age ($P = 0.008$) were significantly associated with changes in BMI. With the exception of age and BMI in the previous checkup, 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, drinking infrequently, and not obtaining adequate sleep were associated with reductions in BMI. Skipping breakfast 3 times or more per week, habitual smoking, and the use of anti-diabetic medication were not significantly associated with BMI.

Discussion

This study analyzed Japanese men and women who had undergone specific health checkups regardless of obesity status. Possible lifestyle-related determinants of obesity were identified using questionnaire items from the Standard Health Checkup and Counseling Guidance Program.[12] 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.

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

The major finding of this study is that changes in eating speed affect obesity and BMI. 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 noncommunicable diseases. Eating quickly is associated with impaired glucose tolerance and insulin resistance,[16,17] and is a known risk factor for diabetes through increases in body weight.[18] Other studies have also reported associations between eating quickly and increased BMI, indicating that eating speed is a contributing factor for obesity.[7,8,19-24] 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.[25] In contrast, eating slowly may help to increase feelings of satiety before an excessive amount of food is ingested.[26-28] A prospective study of schoolgirls found that the reduction of eating speed was able to suppress weight gain and prevent obesity.[29] The findings of these studies are consistent with those of our analysis.

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.[7] 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.[7,9,30] Our generalized 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.[31] Consistently eating breakfast may therefore help to control obesity and BMI.

Daily alcohol consumption has been reported to be positively associated with obesity, and is another risk factor of metabolic syndrome.[7,32] However, our findings indicated that alcohol consumption frequency was not significantly associated with obesity. Previous studies have reported that the frequency of alcohol consumption (given the same quantities of alcohol) was inversely associated with obesity.[33,34] It is possible that the subjects in this study who drank with higher frequency were consuming moderate quantities of alcohol, whereas the subjects who drank infrequently consumed larger quantities during each session.

Studies have also found associations between short sleep durations and BMI increases, and that poor-quality sleep is associated with metabolic syndrome.[35-37] Our analysis produced contradictory results in that a change from adequate sleep to inadequate sleep would reduce BMI but increase obesity progression. A recent study has shown that unstable sleep patterns may increase the quantity of food intake,[38] 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,[7,39] which corroborates our findings.

This study has several limitations that should be considered. First, this study utilized health checkup 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 generalizability 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 standardized questionnaires have been described,[41] Sasaki *et al*. reported that there was no difference between the eating speeds assessed by study subjects or by friends of the subjects.[23] 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.[28] Thirdly, we did not include an analysis of physical exercise. Nevertheless, a previous analysis has reported that eating speed was associated with obesity regardless of the level of physical activity.[24] In addition, other studies have reported similar associations between eating speed and BMI given similar overall food intake, which corroborates our findings.[22,23] Finally, the sample comprised relatively health-conscious individuals who voluntarily participated in health checkups. 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.[7,8,16-29] However, this study utilized panel data to show that changes in eating habits have a causal relationship with obesity and BMI. 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 and BMI. Interventions aimed at altering eating habits, such as education initiatives and programs to reduce eating speed, may be useful in preventing obesity and reducing the risk of noncommunicable diseases.

References

1. World Health Organization. Media centre, obesity and overweight. http://www.who.int/mediacentre/factsheets/fs311/en/ [Accessed: August 19, 2017]
2. 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.
3. Yoon KH, Lee JH, Kim JW, *et al*. Epidemic obesity and type 2 diabetes in Asia, *Lancet* 2006; 368: 1681-8.
4. Huxley R, Mendis S, Zheleznyakov E, *et al*. Body mass index, waist circumference and waist:hip ratio as predictors of cardiovascular risk. *Eur J Clin Nutr* 2010; 64: 16-22.
5. 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.
6. 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: August 19, 2017]
7. 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(4): 176-85.
8. 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.
9. 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.
10. 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.
11. 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.

12. 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_iryou/kenkou/seikatsu/ [Accessed: August 19, 2017]

13. WHO Expert Consultation. Public health appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet* 2004; 363: 157-63.

14. Saito Y, Shirai K, Nakamura T, *et al*. Diagnostic criteria for obesity 2011. *Obesity Research* 2011; 7: s1-s78 [in Japanese]

15. Kitamura Y. Meanings of panel data and its use. *The Japanese Journal of Labour Studies* 2006; 551: 6-16 [in Japanese]

16. 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-e74.

17. 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.

18. Sakurai M, Nakamura K, Miura K, *et al*. Self-reported speed of eating and 7-year risk of type2 diabetes mellitus in middle-aged Japanese men. *Metabolism* 2012; 61: 1566-71.

19. Yamane M, Ekumi D, Kataoka K, *et al*. Relationships between eating quickly and weight gain in Japanese university students: a longitudinal study. *Obesity* 2014; 22: 2262-6.

20. 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.

21. 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. *The Journal*

of Metabolism and Clinical Nutrition 2011; 14: 25-32. [in Japanese]

22. 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.
23. 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.
24. 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. *Journal of the Japanese Association of Rural Medicine* 2010: 58; 533-40. [in Japanese]
25. 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 study. *BMJ* 2008; 337: a2002.
26. 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.
27. 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.
28. Spiegel TA, Wadden TA, Foster GD. Objective measurement of eating rate during behavioral treatment of obesity. *Behav Ther* 1991; 22: 61-7.
29. 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.
30. Odegaard AO, Jacobs DR Jr, Steffen LM, *et al*. Breakfast frequency and development of metabolic risk. *Diabetes Care* 2013; 36: 3100-6.
31. 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.
32. 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.

33. 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.

34. 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.

35. 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.

36. 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.

37. 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.

38. Lundahl A, Nelson T. Sleep and food intake: A multisystem review of mechanisms in children and adults. *J Health Psychol* 2015; 20: 794-805.

39. 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]

40. Yamauchi T, Takaki M, Tonai M. Images and recognition about "eating quickly". *The Journal of Japan Society for Health Care Management* 2003; 4(2): 311-318. [in Japanese]

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

	Eating Speed			
	Fast (n = 22,062)	**Normal (n = 33,460)**	**Slow (n = 4,191)**	***P***
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 test
428 [b] One-way analysis of variance
429 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.

Table 2. Estimated odds ratios of the determinants of obesity derived from the 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

Table 3. Estimated coefficients of the determinants of changes in BMI derived 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

Abbreviation: BMI, body mass index.

BMJ Open

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

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-019589.R1
Article Type:	Research
Date Submitted by the Author:	13-Nov-2017
Complete List of Authors:	Hurst, Yumi; Kyushu University, Department of Health Care Administration and Management Fukuda , H ; Kyushu University, Department of Health Care Administration and Management
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology
Keywords:	PUBLIC HEALTH, obesity, Body mass index, eating habits, health checkups

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

Hurst Y, Fukuda H.

Department of Health Care Administration and Management,
Kyushu University Graduate School of Medical Sciences
3-1-1, Maidashi, Higashi-ku, Fukuoka, 812-8582, Japan

Corresponding Author
Haruhisa Fukuda, MPH, PhD
Department of Health Care Administration and Management, Kyushu University Graduate School of Medical Sciences
3-1-1 Maidashi Higashi-ku Fukuoka 812-8582, Japan
Phone: +81-92-642-6956 Fax: +81-92-642-6961
Email address: h_fukuda@hcam.med.kyushu-u.ac.jp

Abstract

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

Methods Patient-level panel data from 2008 to 2013 were generated using commercially available insurance claims data and health checkup 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 checkups. 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 generalized estimating equation model and fixed-effects model were used to examine the effects of these habits on obesity and BMI, respectively.

Results The generalized estimating equation model showed that eating slower inhibited the development of obesity. The odds ratios 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 model showed that eating slower reduced BMIs. Relative to fast eaters, the coefficients 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 and BMI. Interventions aimed at reducing eating speed may be effective in preventing obesity and lowering the associated health risks.

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

Strengths and limitations of this study

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

Introduction

Excess body weight and obesity can lead to an increased risk of developing noncommunicable diseases such as diabetes, cardiovascular disease, and various forms of cancer.[1-4] Studies have reported that the regulation of body weight can be effective in lowering these health risks.[1-4] However, a 10-year longitudinal study of Japanese men aged 40 to 69 years found that the proportion of overweight and obese individuals had increased over the study period.[5] 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.[6] 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.[1] However, recent studies have reported that excess weight gain and metabolic syndrome are affected not only by energy intake, but are also influenced by other factors such as eating speed, eating frequency, and other lifestyle habits.[7-10] In addition to emphasizing 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 program (Standard Health Checkup and Counseling Guidance Program) to detect risk factors for obesity and metabolic syndrome.[11,12] Under this program, insurers conduct "specific health checkups" aimed at insurance enrollees aged 40 years or older. However, participation in these checkups 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 BMI[13], and that BMI is an independent risk factor for this condition[14]. 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 utilize panel data to analyze the effects of changes in eating speed and other lifestyle habits on obesity. For this analysis, we hypothesized 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 organization that collects, curates, and distributes health-related data. The database comprised insurance claims data and health checkup 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 checkup data included the dates of checkups, body mass index (BMI), waist circumference, blood pressure, and the results of blood chemical analysis, liver function test, blood glucose test, and urinalysis. The health checkup data also included the subjects' responses to several questions regarding lifestyle factors, such as eating habits, alcohol consumption, tobacco use, and sleeping habits.[12] The claims data and health checkup data were linked at the individual subject level for analysis. Approval for this study was obtained from the ethics committee of the JMDC.

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 checkup 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 anti-diabetic medication. The claims data were linked with the health checkup 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 checkup during the study period were used as the baseline values.

Outcomes

The primary outcome of this study was obesity status. According to the World Health Organization'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.[15] 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.[16] In accordance with this recommendation, our study uses a BMI cut-off point of 25 to identify obese individuals. The secondary outcome of this study was BMI, which was analyzed as a continuous variable.

Exposure variables

The exposure variables consisted of the 7 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 3 times or more per week, snacking after dinner for 3 times or more per week, skipping breakfast 3 times or more per week, alcohol consumption frequency, sleep adequacy, and habitual smoking. These variables were analyzed as categorical variables based on the response options. Eating speed was analyzed as 3 categories ("fast", "normal", and "slow"). Eating dinner within 2 hours before sleeping for 3 times or more per week, snacking after dinner for 3 times or more per week, skipping breakfast 3 times or more per week, adequate sleep, and habitual smoking were analyzed as 2 categories ("yes" and "no"). Alcohol consumption frequency was analyzed as 3 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 anti-diabetic medication (as an indicator of diabetes that requires pharmacologic treatment), age, as well as obesity status and BMI in the previous checkup. The use or non-use of anti-diabetic medication was determined based on whether the patient had been administered anti-diabetic medication at the time of each health checkup. This variable was analyzed as 2 categories ("yes" and "no"). In addition to human insulin preparations and insulin analogs, anti-diabetic medications also included sulfonylureas, biguanide derivatives, glitazones, α-glucosidase inhibitors, glinides, DPP-4 inhibitors, and GLP-1 receptor agonists. Age and BMI in the previous checkup were analyzed as continuous variables. Obesity status in the previous checkup was analyzed as 2 categories ("yes" for BMI ≥25 and "no" for BMI <25).

Statistical analysis

The subject baseline characteristics of sex, age, BMI, obesity status, and lifestyle habits were compared among the 3 eating speed categories using the χ^2 test or one-way analysis of variance. Patient-level panel data were generated using repeated estimates from multiple health checkups. This study used longitudinal data from annual health checkups 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 (e.g., fast to fast, fast to normal, fast to slow, and so on) in individual subjects.

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

In order to estimate the influence of changes in eating speed on BMI, we utilized a fixed-effects model where the dependent variable was BMI. The exposure variables were the 7 lifestyle habit items, and the covariates were the use of anti-diabetic medication, age, and BMI in the previous checkup. 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 13.1 (Stata Corp., College Station, TX, USA). Statistical significance was set at $P < 0.05$.

Results

We identified 92,363 individuals from 303,361 person-months who had been diagnosed with type 2 diabetes and had health checkup 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 59,717 individuals from 129,978 person-months. The claims data and health checkup 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±4.0), lower proportion of obese individuals (21.5%), 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 2 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±4.4, $P < 0.001$) and higher proportion of obese individuals (44.8%, $P < 0.001$).

Table 2 shows the estimated odds ratios (ORs) of the various determinants of obesity derived from the generalized estimating equation model. All eating habit items, alcohol consumption frequency, sleep adequacy, and obesity status in the previous checkup 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, inadequate sleep was significantly associated with a higher OR for obesity (1.06, $P = 0.007$). Habitual smoking was also significantly associated with the outcome.

The estimated coefficients of the various determinants of changes in BMI are presented in Table 3. Eating speed (normal: $P < 0.001$; slow: $P < 0.001$), eating dinner within 2 hours before sleeping for 3 times or more per week ($P < 0.001$), snacking after dinner for 3 times or more per week ($P < 0.001$), BMI in the previous checkup ($P < 0.001$), alcohol consumption frequency (occasionally: $P < 0.001$; rarely or never: $P = 0.002$), sleep adequacy ($P < 0.001$), and age ($P = 0.008$) were significantly associated with changes in BMI. With the exception of age and BMI in the previous checkup, 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, drinking infrequently, and not obtaining adequate sleep were associated with reductions in BMI. Skipping breakfast 3 times or more per week, habitual smoking, and the use of anti-diabetic medication were not significantly associated with BMI.

Discussion

This study analyzed Japanese men and women who had undergone specific health checkups regardless of obesity status. Possible lifestyle-related determinants of obesity were identified using questionnaire items from the Standard Health Checkup and Counseling Guidance Program.[12] 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 utilization of large-scale panel data from approximately 60,000 diabetes patients 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.[17] Panel data also enable adjustments of the unobservable differences between study subpopulations, thereby facilitating analyses of the effects of behavioral changes in subjects. Another strength of this study is the incorporation of data on lifestyle habits, such as eating, sleeping, and smoking. By analyzing 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 and BMI. 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 noncommunicable diseases. Eating quickly is associated with impaired glucose tolerance and insulin resistance,[18,19] and is a known risk factor for diabetes through increases in body weight.[20] Other studies have also reported associations between eating quickly and increased BMI, indicating that eating speed is a contributing factor for obesity.[7,8,21-26] 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.[27] In contrast, eating slowly may help to increase feelings of satiety before an excessive amount of food is ingested.[28-30] A prospective study of schoolgirls found that the reduction of eating speed was able to suppress weight gain and prevent obesity.[31] 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.[32] 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.[7] 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.[7,9,33] Our generalized 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.[34] Consistently eating breakfast may therefore help to control obesity and BMI.

Daily alcohol consumption has been reported to be positively associated with obesity, and is another risk factor of metabolic syndrome.[7,35] However, our findings indicated that alcohol consumption frequency was not significantly associated with obesity. Previous studies have reported that the frequency of alcohol consumption (given the same quantities of alcohol) was inversely associated with obesity.[36,37] It is possible that the subjects in this study who drank with higher frequency were consuming moderate quantities of alcohol, whereas the subjects who drank infrequently consumed larger quantities during each session.

Studies have also found associations between short sleep durations and BMI increases, and that poor-quality sleep is associated with metabolic syndrome.[38-40] Our analysis produced contradictory results in that a change from adequate sleep to inadequate sleep would reduce BMI but increase obesity progression. A recent study has shown that unstable sleep patterns may increase the quantity of food intake,[41] 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,[7,42] which corroborates our findings.

This study has several limitations that should be considered. First, this study utilized health checkup 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 generalizability 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 standardized questionnaires have been described,[43] Sasaki *et al*. reported that there was no difference between the eating speeds assessed by study subjects or by friends of the subjects.[25] 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.[30] Thirdly, 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.[26] Other studies have also reported similar associations between eating speed

311 and BMI given similar overall food intake, which corroborates our findings.[24,25]
312 Therefore, these 2 factors are unlikely to be confounders in this study despite their
313 association with BMI. Finally, the sample comprised relatively health-conscious
314 individuals who voluntarily participated in health checkups. The findings may
315 therefore have limited applicability to less health-conscious people.
316 Many studies have shown that eating habits are associated with BMI and weight
317 gain.[7,8,18-31] However, this study utilized panel data to show that changes in eating
318 habits have a strong relationship with obesity and BMI. These findings indicate that
319 weight loss can be supported through the reduction of eating speed, the cessation of
320 eating dinner within 2 hours before sleeping, the cessation of snacking after dinner,
321 and consistently having breakfast.
322

323 **Conclusions**

324 Changes in eating habits can affect obesity and BMI. Interventions aimed at altering
325 eating habits, such as education initiatives and programs to reduce eating speed, may
326 be useful in preventing obesity and reducing the risk of noncommunicable diseases.
327

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:

No potential conflicts of interest relevant to this article were reported.

Author contributions:

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.

Ethics approval:

This study was approved by the ethics committee of the Japan Medical Data Center.

Data sharing statement:

No additional data are available.

References

1. World Health Organization. Media centre, obesity and overweight. http://www.who.int/mediacentre/factsheets/fs311/en/ [Accessed: August 19, 2017]
2. 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.
3. Yoon KH, Lee JH, Kim JW, *et al*. Epidemic obesity and type 2 diabetes in Asia, *Lancet* 2006; 368: 1681-8.
4. Huxley R, Mendis S, Zheleznyakov E, *et al*. Body mass index, waist circumference and waist:hip ratio as predictors of cardiovascular risk. *Eur J Clin Nutr* 2010; 64: 16-22.
5. 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.
6. 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: August 19, 2017]
7. 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(4): 176-85.
8. 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.
9. 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.
10. 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.
11. 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.

12. 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_iryou/kenkou/seikatsu/ [Accessed: August 19, 2017]

13. 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 Research* 2000; 6: 4-17. [in Japanese]

14. 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. *Diabetic Medicine* 2005; 22(3): 323-31.

15. WHO Expert Consultation. Public health appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet* 2004; 363: 157-63.

16. Saito Y, Shirai K, Nakamura T, *et al*. Diagnostic criteria for obesity 2011. *Obesity Research* 2011; 7: s1-s78 [in Japanese]

17. Kitamura Y. Meanings of panel data and its use. *The Japanese Journal of Labour Studies* 2006; 551: 6-16 [in Japanese]

18. 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-e74.

19. 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.

20. Sakurai M, Nakamura K, Miura K, *et al*. Self-reported speed of eating and 7-year risk of type2 diabetes mellitus in middle-aged Japanese men. *Metabolism* 2012; 61: 1566-71.

21. Yamane M, Ekumi D, Kataoka K, *et al*. Relationships between eating quickly and weight gain in Japanese university students: a longitudinal study. *Obesity* 2014; 22:

2262-6.

22. 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.

23. 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. *The Journal of Metabolism and Clinical Nutrition* 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. *Journal of the Japanese Association of Rural Medicine* 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 study. *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 Clinic Proceedings* 2014; 89(3): 335-45.

33. Odegaard AO, Jacobs DR Jr, 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 T. 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]

462 43. Yamauchi T, Takaki M, Tonai M. Images and recognition about "eating quickly". *The Journal of Japan Society for Health Care Management* 2003; 4(2): 311-318. [in Japanese]

465

Table 1. Distribution of baseline characteristics according to eating speed

	Eating Speed			
	Fast (n = 22,062)	**Normal (n = 33,460)**	**Slow (n = 4,191)**	***P***
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]

[a] χ^2 test
[b] One-way analysis of variance
Values for number of checkups, age, and BMI are presented as mean [standard deviation]. All other values are presented as number of subjects (proportion of each eating-speed group).
Abbreviation: BMI, body mass index.

Table 2. Estimated odds ratios of the determinants of obesity derived from the 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

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 2: 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*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection ofparticipants. Describe methods of follow-up *Case-control study*—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 *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	Page 5: Lines 112-114	
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—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*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	Not Applicable
		(*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) *Cohort study*—Summarise follow-up time (eg, average and total amount)	Page 20: Line 183-184
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Page 20: Table 1
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	Page 20: Table 1
		Cross-sectional study—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

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.

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

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-019589.R2
Article Type:	Research
Date Submitted by the Author:	09-Dec-2017
Complete List of Authors:	Hurst, Yumi; Kyushu University, Department of Health Care Administration and Management Fukuda , H ; Kyushu University, Department of Health Care Administration and Management
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology
Keywords:	PUBLIC HEALTH, obesity, Body mass index, eating habits, health checkups

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

Hurst Y, Fukuda H.

Department of Health Care Administration and Management,
Kyushu University Graduate School of Medical Sciences
3-1-1, Maidashi, Higashi-ku, Fukuoka, 812-8582, Japan

Corresponding Author
Haruhisa Fukuda, MPH, PhD
Department of Health Care Administration and Management,
Kyushu University Graduate School of Medical Sciences
3-1-1 Maidashi Higashi-ku Fukuoka 812-8582, Japan
Phone: +81-92-642-6956 Fax: +81-92-642-6961
Email address: h_fukuda@hcam.med.kyushu-u.ac.jp

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 analyze the effects of changes in lifestyle habits on changes in obesity utilizing panel data.

Methods Patient-level panel data from 2008 to 2013 were generated using commercially available insurance claims data and health checkup 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 checkups. 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 generalized 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 generalized estimating equation model showed that eating slower inhibited the development of obesity. The odds ratios 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.

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

Strengths and limitations of this study

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

Introduction

Excess body weight and obesity can lead to an increased risk of developing noncommunicable diseases such as diabetes, cardiovascular disease, and various forms of cancer.[1-4] Studies have reported that the regulation of body weight can be effective in lowering these health risks.[1-4] However, a 10-year longitudinal study of Japanese men aged 40 to 69 years found that the proportion of overweight and obese individuals had increased over the study period.[5] 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.[6] 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.[1] However, recent studies have reported that excess weight gain and metabolic syndrome are affected not only by energy intake, but are also influenced by other factors such as eating speed, eating frequency, and other lifestyle habits.[7-10] In addition to emphasizing 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 program (Standard Health Checkup and Counseling Guidance Program) to detect risk factors for obesity and metabolic syndrome.[11,12] Under this program, insurers conduct "specific health checkups" aimed at insurance enrollees aged 40 years or older. However, participation in these checkups 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 BMI[13], and that BMI is an independent risk factor for this condition[14]. 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 utilize panel data to analyze the effects of changes in eating speed and other lifestyle habits on obesity in patients with type 2 diabetes. For this analysis, we hypothesized 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 organization that collects, curates, and distributes health-related data. The database comprised insurance claims data and health checkup 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 checkup data included the dates of checkups, body mass index (BMI), waist circumference, blood pressure, and the results of blood chemical analysis, liver function test, blood glucose test, and urinalysis. The health checkup data also included the subjects' responses to several questions regarding lifestyle factors, such as eating habits, alcohol consumption, tobacco use, and sleeping habits.[12] The claims data and health checkup data were linked at the individual subject level for analysis. Approval for this study (No. 18-09-2014) was obtained from the ethics committee of the JMDC.

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 checkup 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 anti-diabetic medication. The claims data were linked with the health checkup 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 checkup during the study period were used as the baseline values.

Outcomes

The primary outcome of this study was obesity status. According to the World Health Organization'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.[15] 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.[16] 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 analyzed as continuous variables.

Exposure variables

The exposure variables consisted of the 7 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 3 times or more per week, snacking after dinner for 3 times or more per week, skipping breakfast 3 times or more per week, alcohol consumption frequency, sleep adequacy, and habitual smoking. These variables were analyzed as categorical variables based on the response options. Eating speed was analyzed as 3 categories ("fast", "normal", and "slow"). Eating dinner within 2 hours before sleeping for 3 times or more per week, snacking after dinner for 3 times or more per week, skipping breakfast 3 times or more per week, adequate sleep, and habitual smoking were analyzed as 2 categories ("yes" and "no"). Alcohol consumption frequency was analyzed as 3 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 anti-diabetic medication (as an indicator of diabetes that requires pharmacologic treatment), age, as well as obesity status and BMI in the previous checkup. The use or non-use of anti-diabetic medication was determined based on whether the patient had been administered anti-diabetic medication at the time of each health checkup. This variable was analyzed as 2 categories ("yes" and "no"). In addition to human insulin preparations and insulin analogs, anti-diabetic medications also included sulfonylureas, biguanide derivatives, glitazones, α-glucosidase inhibitors, glinides, DPP-4 inhibitors, and GLP-1 receptor agonists. Age and BMI in the previous checkup were analyzed as continuous variables. Obesity status in the previous checkup was analyzed as 2 categories ("yes" for BMI ≥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 3 eating speed categories using the χ^2 test or one-way analysis of variance. Patient-level panel data were generated using repeated estimates from multiple health checkups. This study used longitudinal data from annual health checkups 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 (e.g., fast to fast, fast to normal, fast to slow, and so on) in individual subjects.

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

In order to estimate the influence of changes in eating speed on BMI and waist circumference, we utilized fixed-effects models with these factors as the dependent variables. The exposure variables were the 7 lifestyle habit items, and the covariates were the use of anti-diabetic medication, age, and BMI or waist circumference in the previous checkup. 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 13.1 (Stata Corp., College Station, TX, USA). Statistical significance was set at $P < 0.05$.

Results

We identified 92,363 individuals from 303,361 person-months who had been diagnosed with type 2 diabetes and had health checkup 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 59,717 individuals from 129,978 person-months. The claims data and health checkup 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±4.0), lower proportion of obese individuals (21.5%), smaller mean waist circumference (80.1±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 2 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±4.4, $P < 0.001$), higher proportion of obese individuals (44.8%, $P < 0.001$), and larger mean waist circumference (86.8±11.1 cm, $P < 0.001$).

The mean number (and standard deviation) of health checkups among the 59,171 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 checkups undergone during the study period was as follows: 21,805 subjects (36.5%) with 1 checkup, 17,694 (29.6%) subjects with 2 checkups, 12,075 (20.2%) subjects with 3 checkups, 4,524 (7.6%) subjects with 4 checkups, 3,248 (5.4%) subjects with 5 checkups, and 371 (0.6%) subjects with 6 checkups. Table 2 shows the changes in eating speed across these checkups 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 odds ratios (ORs) of the various determinants of obesity derived from the generalized estimating equation model. All eating habit items, alcohol consumption frequency, sleep adequacy, and obesity status in the previous checkup 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

230 dinner within 2 hours before sleeping for 3 times or more per week ($P < 0.001$), snacking after dinner for 3 times or more per week ($P < 0.001$), BMI in the previous checkup ($P < 0.001$), 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 checkup, 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 3 times or more per week, habitual smoking, and the use of anti-diabetic medication were not significantly associated with BMI.

240 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 ($P < 0.001$).

245 **Discussion**

This study analyzed Japanese men and women who had undergone specific health checkups regardless of obesity status. Possible lifestyle-related determinants of obesity were identified using questionnaire items from the Standard Health Checkup and Counseling Guidance Program.[12] 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.

255 A strength of this study is the utilization of large-scale panel data from approximately 60,000 diabetes patients 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.[17] Panel data also enable adjustments of the unobservable differences between study subpopulations, thereby facilitating analyses of the effects of behavioral changes in subjects. Another strength of this study is the incorporation of data on lifestyle habits, such as eating, sleeping, and smoking. By analyzing 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 noncommunicable diseases. Eating quickly is associated with impaired glucose tolerance and insulin resistance,[18,19] and is a known risk factor for diabetes through increases in body weight.[20] Other studies have also reported associations between eating quickly and increased BMI, indicating that eating speed is a contributing factor for obesity.[7,8,21-26] 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.[27] In contrast, eating slowly may help to increase feelings of satiety before an excessive amount of food is ingested.[28-30] A prospective study of schoolgirls found that the reduction of eating speed was able to suppress weight gain and prevent obesity.[31] 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.[32] 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.[7] 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.[7,9,33] Our generalized 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.[34] 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,[7,35] others have reported an inverse association between the frequency of alcohol consumption (given the same quantities of alcohol) and obesity.[36,37] 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.[38-40] 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,[41] 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,[7,42] which corroborates our findings.

This study has several limitations that should be considered. First, this study utilized health checkup 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 generalizability 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 standardized questionnaires have been described,[43] Sasaki *et al*. reported that there was no difference between the eating speeds assessed by study subjects or by friends of the subjects.[25] 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.[30] Thirdly, 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.[26] Other studies have also reported similar associations between eating speed and BMI given similar overall food intake, which corroborates our findings.[24,25] Therefore, these 2 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 checkups. 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.[7,8,18-31] However, this study utilized 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 programs to reduce eating speed, may be useful in preventing obesity and reducing the risk of noncommunicable diseases.

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:

No potential conflicts of interest relevant to this article were reported.

Author contributions:

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

Ethics approval:

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

Data sharing statement:

No additional data are available.

References

1. World Health Organization. Media centre, obesity and overweight. http://www.who.int/mediacentre/factsheets/fs311/en/ [Accessed: August 19, 2017]
2. 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.
3. Yoon KH, Lee JH, Kim JW, *et al*. Epidemic obesity and type 2 diabetes in Asia, *Lancet* 2006; 368: 1681-8.
4. Huxley R, Mendis S, Zheleznyakov E, *et al*. Body mass index, waist circumference and waist:hip ratio as predictors of cardiovascular risk. *Eur J Clin Nutr* 2010; 64: 16-22.
5. 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.
6. 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: August 19, 2017]
7. 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(4): 176-85.
8. 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.
9. 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.
10. 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.
11. 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.

12. 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_iryou/kenkou/seikatsu/ [Accessed: August 19, 2017]
13. 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 Research* 2000; 6: 4-17. [in Japanese]
14. 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. *Diabetic Medicine* 2005; 22(3): 323-31.
15. WHO Expert Consultation. Public health appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet* 2004; 363: 157-63.
16. Saito Y, Shirai K, Nakamura T, *et al*. Diagnostic criteria for obesity 2011. *Obesity Research* 2011; 7: s1-s78 [in Japanese]
17. Kitamura Y. Meanings of panel data and its use. *The Japanese Journal of Labour Studies* 2006; 551: 6-16 [in Japanese]
18. 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-e74.
19. 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.
20. Sakurai M, Nakamura K, Miura K, *et al*. Self-reported speed of eating and 7-year risk of type2 diabetes mellitus in middle-aged Japanese men. *Metabolism* 2012; 61: 1566-71.
21. Yamane M, Ekumi D, Kataoka K, *et al*. Relationships between eating quickly and weight gain in Japanese university students: a longitudinal study. *Obesity* 2014; 22:

2262-6.

22. 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.

23. 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. *The Journal of Metabolism and Clinical Nutrition* 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. *Journal of the Japanese Association of Rural Medicine* 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 study. *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 Clinic Proceedings* 2014; 89(3): 335-45.

33. Odegaard AO, Jacobs DR Jr, 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 T. 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]

488 43. Yamauchi T, Takaki M, Tonai M. Images and recognition about "eating quickly". *The Journal of Japan Society for Health Care Management* 2003; 4(2): 311-318. [in Japanese]

Table 1. Distribution of baseline characteristics according to eating speed

	Eating Speed			*P*
	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/m2	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]

[a] χ^2 test

[b] One-way analysis of variance

Values for number of checkups, age, and BMI are presented as mean [standard deviation]. All other values are presented as number of subjects (proportion of each eating-speed group).

Abbreviation: 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%)
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%)

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

[a] Subjects with only 2 eating speed measurements during the study period.

[b] Subjects with only 1 eating speed measurement during the study period.

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

Table 4. Estimated coefficients of the determinants of changes in BMI derived 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

Abbreviation: BMI, body mass index.

Table 5. Estimated coefficients of the determinants of changes in waist 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

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 2: 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*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection ofparticipants. Describe methods of follow-up *Case-control study*—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 *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	Page 5: Lines 112-114	
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—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*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	Not Applicable
		(*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) *Cohort study*—Summarise follow-up time (eg, average and total amount)	Page 20: Line 183-184
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Page 20: Table 1
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	Page 20: Table 1
		Cross-sectional study—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

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.