

Impact of eating rate on obesity and cardiovascular risk factors according to glucose tolerance status: the Fukuoka Diabetes Registry and the Hisayama Study

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Abstract

Aims/hypothesis Medical nutrition therapy plays a critical role in the prevention and treatment of type 2 diabetes. However, appropriate measures of eating behaviours, such as eating rate, have not yet been clearly established. The aim of the present study was to examine the associations among eating rate, obesity and cardiovascular risk factors.

Methods A total of 7,275 Japanese individuals aged ≥ 40 years who had normal fasting glucose levels, impaired fasting glucose or diabetes were divided into four groups

according to self-reported eating rate: slow, medium, relatively fast and very fast. The associations between eating rate and various cardiovascular risk factors were investigated cross-sectionally.

Results The proportions of participants who were obese or who had elevated waist circumference levels increased progressively with increases in eating rate (p for trend < 0.001), regardless of glucose tolerance status. These associations remained significant after adjustment for potential confounders, namely, age, sex, total energy intake, dietary fibre intake, current smoking, current drinking and regular exercise (p for trend < 0.001). Blood pressure and lipid levels also tended to increase in association with eating rate. HbA_{1c} rose significantly as eating rate increased, even after multivariate adjustment, including BMI, in diabetic patients on insulin therapy ($p = 0.02$), whereas fasting plasma glucose did not increase significantly.

Conclusions/interpretation Our findings suggest that eating rate is associated with obesity and other cardiovascular risk factors and therefore may be a modifiable risk factor in the management of cardiovascular risk factors and diabetes.

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Key words Cardiovascular risk factors · Cross-sectional study · Eating behaviour · Eating fast · Eating rate · Epidemiology · Impaired fasting glucose · Obesity · Speed of eating · Type 2 diabetes mellitus

Abbreviations

FPG Fasting plasma glucose
GLP-1 Glucagon-like peptide-1
IFG Impaired fasting glucose
OHA Oral hypoglycaemic agent

Introduction

The epidemic of type 2 diabetes mellitus and its complications, including both macro- and microvascular diseases, is a major public health concern in developing as well as developed countries [1]. This epidemic is most likely the result of population growth, ageing and the increasing prevalence of obesity resulting from environmental factors such as urbanisation, physical inactivity and increased food consumption [2]. The clustering of multiple cardiovascular risk factors, such as elevated waist circumference, elevated blood pressure, glucose intolerance and dyslipidaemia, is also associated with the development of type 2 diabetes and cardiovascular diseases worldwide, including Japan [3, 4]. The burden of diseases associated with type 2 diabetes is an important problem in global healthcare systems. Therefore, a practical and effective approach for the treatment of these diseases in the clinical setting is essential.

Medical nutrition therapy plays a critical role in the treatment of these diseases. Although there are recommendations regarding energy balance and macro- and micronutrient intake [5, 6], measures of appropriate eating behaviours have not been well established. The eating rate of obese people has been investigated, and eating slowly has been considered to be a simple and effective therapy for obesity [7]. Recently, several epidemiological studies conducted among healthy participants have shown positive associations between eating quickly and obesity [8–12] and metabolic syndrome [13]. However, it is not certain whether these findings are also applicable to those with abnormal glucose regulation. Although several studies conducted among healthy participants have indicated an association between eating quickly and elevated glycaemic levels [12, 14], few have been conducted to clarify this association in diabetic patients. In addition, to the best of our knowledge, no large-scale epidemiological studies have evaluated the relationships between the speed of eating and glycaemic control or coexisting cardiovascular risk factors in type 2 diabetic patients. Therefore, the objective of the current study was to examine the associations between eating rate and glycaemic levels, obesity and cardiovascular risk factors in a cross-sectional study of participants with differing status of glucose tolerance, while also taking into account comprehensive confounders.

Methods

Study participants The Fukuoka Diabetes Registry is a multicentre prospective study designed to investigate the influence of modern treatment on the prognoses of diabetic patients attending teaching hospitals certified by the Japan Diabetes Society or certified diabetes clinics in Fukuoka

Prefecture, Japan (UMIN Clinical Trial Registry 000002627). A total of 5,131 diabetic patients were registered between April 2008 and October 2010. The exclusion criteria were: (1) patients with drug-induced diabetes or those undergoing steroid treatment; (2) patients undergoing renal replacement therapy; (3) patients with serious diseases other than diabetes, such as advanced malignancies and decompensated liver cirrhosis; and (4) patients unable to visit diabetologists regularly. In addition, 3,351 participants of a health survey in the Hisayama Study conducted in 2009 were recruited for the present study. The Hisayama Study is a population-based prospective study in the town of Hisayama in Fukuoka Prefecture that has been underway since 1961 [15]. Out of a total of 8,482 participants, we excluded 269 who were below 40 years of age, 209 with type 1 diabetes, 488 who had already eaten breakfast, 239 with missing values in the lifestyle and dietary survey and two without measurements of waist circumference. The remaining 7,275 participants (3,737 males, 3,538 females) were enrolled in this cross-sectional study.

Participants were divided into those with normal glucose levels and those with impaired fasting glucose (IFG) or diabetes, based on fasting plasma glucose (FPG) levels and a medical history of diabetes [16], i.e. FPG <5.6 mmol/l for normal glucose, FPG 5.6–6.9 mmol/l for IFG, and FPG \geq 7.0 mmol/l and/or previously diagnosed diabetes for diabetes. This study was conducted with the approval of the Kyushu University Institutional Review Board, and written informed consent was obtained from all participants.

Clinical evaluation and laboratory measurements A dietary survey was conducted using a brief-type self-administered diet history questionnaire regarding the food frequency of 58 items (BDHQ; Gender Medical Research, Tokyo, Japan). The validation of ranking the energy-adjusted intake of many nutrients has been studied in adult Japanese populations [17, 18]. As part of this questionnaire, the speed of eating was investigated by the question: How fast is your speed of eating? The answer was chosen from the following five categories: very slow, relatively slow, medium, relatively fast, very fast. The validity and reproducibility of this self-reported question have been previously reported [9, 11]. Because a small number of participants reported being very slow eaters ($n=336$), the very slow and relatively slow categories were combined into one slow category. Participants also completed a self-administered questionnaire covering medical history, medication use, alcohol intake, smoking habits and physical activity. Alcohol intake and smoking habits were classified as either current or not. Participants engaging in regular exercise such as walking and calisthenics during their leisure time were assigned to the regular exercise group.

Blood was collected by venipuncture after an overnight fast. Plasma glucose levels were determined using the glucose-oxidase method; HbA_{1c} levels were determined using HPLC (Tosoh, Tokyo, Japan); and triacylglycerol, HDL-cholesterol and LDL-cholesterol levels were determined using enzymatic methods. Elevated triacylglycerol was defined as levels ≥ 1.68 mmol/l, and reduced HDL-cholesterol was defined as levels < 1.03 mmol/l for males and < 1.29 mmol/l for females [19]. BMI was calculated from height and weight, and obesity was defined as a BMI ≥ 25 kg/m². Waist circumference at the umbilical level was measured by a trained staff member with the participant in the standing position, and elevated waist circumference was defined as a waist circumference level ≥ 90 cm in males and ≥ 80 cm in females [19]. Blood pressure was measured with the participant in the sitting position, and elevated blood pressure was defined as a blood pressure $\geq 130/85$ mmHg and/or current use of antihypertensive agents [19].

Statistical analysis The linear trends of age, sex, lifestyle and dietary factors across the eating rate categories were tested using the Jonckheere–Terpstra test and the Cochran–Armitage test, as appropriate. The age- and sex-adjusted or multivariate-adjusted mean values of the cardiovascular risk factors were calculated using analysis of covariance, and the trends across eating rate were tested using multiple regression analysis. Triacylglycerol values were log-transformed to base *e* for the statistical analyses due to having a skewed distribution, back-transformed and presented with their 95% CIs. The proportions of participants who were obese or who had cardiovascular risk factors were also adjusted for age and sex with a direct method using all study participants as a standard population and then examined for trends using the Cochran–Mantel–Haenszel test. The multivariate-adjusted ORs and their 95% CIs for obesity and cardiovascular risk factors were calculated using a logistic regression model. The linear trends of the ORs across the eating rate categories were also tested using a logistic regression model. All analyses were performed using SAS software version 9.2 (SAS Institute, Cary, NC, USA). Values of $p < 0.05$ were considered to be statistically significant for all analyses.

Results

The clinical characteristics of the study participants are presented in Table 1 according to eating rate category and glucose tolerance status. As the speed of eating increased, the mean age decreased and the proportion of males increased significantly, regardless of glucose tolerance status. Although total energy intakes did not significantly change according to eating rate in any status of glucose tolerance, dietary fibre intakes decreased significantly in association

with increases in eating rate in all groups. The proportion of current smokers increased in the normal and diabetic groups with a faster eating rate, and this trend was also observed in current drinkers in the normal glucose group. The proportion of participants performing regular exercise was not found to be related to the eating rate in any group.

Table 2 shows the age- and sex-adjusted cardiovascular risk factors according to eating rate category and glucose tolerance status. BMI, the proportion of obese participants and waist circumference significantly increased in association with increases in the speed of eating in all glucose tolerance status groups. The mean increase in BMI in the very fast eaters group relative to that in the slow eaters group was 1.9, 2.1 and 1.5 kg/m² in the normal glucose group, IFG group and diabetic group, respectively. The corresponding increases in body weight were 6.2, 7.5 and 4.4 kg, respectively. FPG levels marginally increased in the normal glucose group with increasing eating rate, whereas HbA_{1c} levels significantly increased in the diabetic group only. Systolic blood pressure significantly increased in both the normal and diabetic groups, and diastolic blood pressure significantly increased in the normal glucose group in association with the eating rate. As the eating rate increased, the LDL-cholesterol level significantly increased in the normal and diabetic groups, the HDL-cholesterol level significantly decreased and the triacylglycerol level increased in all three groups.

We additionally analysed the association between eating rate and glycaemic levels by combining the normal and IFG groups into a non-diabetic group or by considering the type of diabetes treatment after controlling for age, sex, total energy intake, dietary fibre intake, current smoking habits, current drinking habits and regular exercise habits. FPG increased as the speed of eating increased in non-diabetic participants, although this association disappeared with additional adjustment for BMI (p for trend=0.25). HbA_{1c} levels did not significantly change. FPG and HbA_{1c} levels did not significantly increase in association with the eating rate in diabetic patients treated with dietary therapy only or oral hypoglycaemic agent (OHA) therapy, after adjustment for confounding factors. FPG did not change significantly (slow 8.34 ± 0.17 [SE] mmol/l; medium 8.22 ± 0.12 mmol/l; relatively fast 8.49 ± 0.14 mmol/l; very fast 8.63 ± 0.20 mmol/l; p for trend=0.13) in insulin-treated patients, whereas a significant upward trend in HbA_{1c} levels was observed in association with a faster eating rate (slow $7.72 \pm 0.07\%$ [SE] [60.9 ± 0.8 mmol/mol]; medium $7.68 \pm 0.05\%$ [60.4 ± 0.6 mmol/mol]; relatively fast $7.88 \pm 0.06\%$ [62.6 ± 0.7 mmol/mol]; very fast $8.01 \pm 0.09\%$ [64.0 ± 1.0 mmol/mol]; p for trend=0.001). This relationship was still significant after further adjustment for BMI (p for trend=0.02).

As shown in Table 3, there were significant upward trends in the ORs for obesity and elevated waist circumference

Table 1 Clinical characteristics of the study participants according to eating rate category and glucose tolerance status

Variable	Glucose tolerance status	Eating rate category				<i>p</i> for trend
		Slow	Medium	Relatively fast	Very fast	
<i>N</i>	Total (<i>n</i> =7,275)	1,358 (19)	2,900 (40)	2,177 (30)	840 (11)	
	Normal glucose (<i>n</i> =1,490)	282 (19)	744 (50)	381 (26)	83 (6)	
	IFG (<i>n</i> =1,009)	176 (17)	479 (47)	262 (26)	92 (9)	
	Diabetes (<i>n</i> =4,776)	900 (19)	1,677 (35)	1,534 (32)	665 (14)	
	Diet only (<i>n</i> =1,030)	186 (18)	373 (36)	326 (32)	145 (14)	
	OHA only (<i>n</i> =2,574)	476 (18)	874 (34)	865 (34)	359 (14)	
	Insulin (<i>n</i> =1,172)	238 (20)	430 (37)	343 (29)	161 (14)	
Age (years)	Normal glucose	67±14	61±12	58±11	58±12	<0.001
	IFG	69±11	64±11	60±10	61±11	<0.001
	Diabetes	69±9	67±9	64±9	66±9	<0.001
Men	Normal glucose	76 (27)	229 (31)	154 (40)	34 (41)	<0.001
	IFG	88 (50)	240 (50)	137 (52)	63 (68)	0.006
	Diabetes	478 (53)	922 (55)	889 (58)	427 (64)	<0.001
Total energy intake (×10 ³ , kJ/day)	Normal glucose	7.3±2.3	7.5±2.4	7.4±2.1	7.8±2.4	0.21
	IFG	7.6±2.5	7.6±2.3	7.6±2.0	8.2±2.5	0.09
	Diabetes	7.1±2.0	7.1±2.0	7.1±2.1	7.4±2.3	0.10
Dietary fibre intake (g/4,184 kJ)	Normal glucose	6.7±1.8	6.6±2.0	6.2±1.9	6.2±2.4	<0.001
	IFG	6.4±1.7	6.3±1.9	5.9±1.7	6.0±2.1	0.003
	Diabetes	7.9±2.3	7.6±2.2	7.3±2.1	7.3±2.2	<0.001
Current smoker	Normal glucose	36 (13)	127 (17)	90 (24)	21 (25)	<0.001
	IFG	41 (23)	95 (20)	67 (26)	23 (25)	0.15
	Diabetes	142 (16)	298 (18)	292 (19)	131 (20)	0.01
Current drinker	Normal glucose	108 (38)	342 (46)	203 (53)	41 (49)	<0.001
	IFG	92 (52)	242 (51)	146 (56)	53 (58)	0.10
	Diabetes	342 (38)	665 (40)	637 (42)	255 (38)	0.23
Regular exercise	Normal glucose	151 (54)	374 (50)	193 (51)	37 (45)	0.12
	IFG	90 (51)	265 (55)	138 (53)	49 (53)	0.47
	Diabetes	614 (68)	1,173 (70)	1,067 (70)	442 (66)	0.27

Values are expressed as mean ± SD or number of participants (%)

in association with increases in the speed of eating, irrespective of glucose tolerance status (all, *p* for trend <0.001), after controlling for the confounding factors listed above. Similar findings were observed for the ORs for elevated blood pressure in the IFG and diabetic groups and the ORs for elevated triacylglycerol in the normal glucose group.

Discussion

In the present study, we clearly demonstrated that the proportions of participants who were obese or who had cardiovascular risk factors increased in association with increases in eating rate, regardless of glucose tolerance status, and that HbA_{1c} levels rose significantly as eating rate increased only in diabetic patients treated with insulin. These relationships remained robust even after controlling for total energy

intake and other confounding factors. To the best of our knowledge, this is the first study to show an association between self-reported eating rate and cardiovascular risk factors in a large number of diabetic patients.

Several epidemiological studies have indicated that eating rate is associated with obesity [9–12] and metabolic syndrome [13] in non-diabetic participants. One preliminary study showed that BMI increased in association with increasing eating rate in diabetic patients, although it did not take into account any confounding factors [8]. One of our co-authors reported an increase in BMI with faster eating rate as assessed by the same questionnaire as that used in the present study and independently of nutrient intake, physical activity or experience of dieting in young females [9]. A rapid eating style has also been shown to be associated with childhood obesity [20]. The present study confirmed the presence of an association between fast eating and obesity

Table 2 Age- and sex-adjusted cardiovascular risk factors according to eating rate category and glucose tolerance status

Variable	Glucose tolerance status	Eating rate category				<i>p</i> for trend
		Slow	Medium	Relatively fast	Very fast	
BMI, kg/m ²	Normal glucose	21.5±0.2	22.1±0.1	22.9±0.2	23.4±0.3	<0.001
	IFG	23.0±0.3	23.7±0.2	24.1±0.2	25.1±0.4	<0.001
	Diabetes	23.2±0.1	23.6±0.1	24.0±0.1	24.7±0.1	<0.001
Obesity, %	Normal glucose	11	17	23	25	<0.001
	IFG	28	30	34	48	<0.001
	Diabetes	26	31	34	44	<0.001
Waist circumference, cm	Normal glucose	80.6±0.5	82.3±0.3	84.9±0.4	86.3±0.9	<0.001
	IFG	84.9±0.7	87.0±0.4	87.2±0.6	89.9±0.9	<0.001
	Diabetes	85.1±0.3	85.5±0.2	86.4±0.3	88.2±0.4	<0.001
FPG, mmol/l	Normal glucose	5.08±0.02	5.13±0.01	5.13±0.01	5.15±0.03	0.03
	IFG	5.98±0.03	5.93±0.01	5.95±0.02	6.00±0.03	0.65
	Diabetes	7.74±0.07	7.66±0.05	7.71±0.05	7.77±0.08	0.63
HbA _{1c} , % (mmol/mol)	Normal glucose	5.34±0.02 (34.9±0.2)	5.33±0.01 (34.7±0.1)	5.31±0.02 (34.6±0.2)	5.31±0.04 (34.6±0.4)	0.24
	IFG	5.59±0.03 (37.6±0.3)	5.56±0.02 (37.2±0.2)	5.61±0.02 (37.8±0.3)	5.58±0.04 (37.5±0.4)	0.62
	Diabetes	7.36±0.04 (56.9±0.4)	7.30±0.03 (56.2±0.3)	7.37±0.03 (57.0±0.3)	7.48±0.04 (58.2±0.4)	0.02
Systolic blood pressure, mmHg	Normal glucose	128±1	129±1	133±1	129±2	0.01
	IFG	136±2	137±1	137±1	139±2	0.21
	Diabetes	131±1	132±0	132±0	133±1	0.03
Diastolic blood pressure, mmHg	Normal glucose	78±1	78±0	80±1	79±1	0.01
	IFG	82±1	83±1	83±1	85±1	0.10
	Diabetes	75±0	76±0	76±0	76±0	0.22
LDL-cholesterol, mmol/l	Normal glucose	2.94±0.04	2.99±0.03	3.06±0.04	3.06±0.08	0.04
	IFG	3.08±0.06	3.16±0.03	3.10±0.05	3.09±0.08	0.82
	Diabetes	2.85±0.02	2.87±0.02	2.90±0.02	2.92±0.03	0.02
HDL-cholesterol, mmol/l	Normal glucose	1.66±0.02	1.68±0.01	1.62±0.02	1.60±0.04	0.049
	IFG	1.57±0.03	1.54±0.02	1.50±0.02	1.43±0.04	0.003
	Diabetes	1.49±0.01	1.49±0.01	1.46±0.01	1.43±0.02	<0.001
Triacylglycerol, mmol/l	Normal glucose	1.08 (1.02, 1.14)	1.10 (1.06, 1.14)	1.17 (1.12, 1.23)	1.17 (1.06, 1.30)	0.02
	IFG	1.32 (1.22, 1.43)	1.30 (1.24, 1.36)	1.36 (1.27, 1.45)	1.55 (1.39, 1.72)	0.02
	Diabetes	1.21 (1.17, 1.26)	1.24 (1.21, 1.27)	1.25 (1.21, 1.28)	1.28 (1.24, 1.34)	0.04

Values are expressed as mean ± SE or percentage

Triacylglycerol levels are presented as geometric means (95% CI)

and metabolic syndrome among non-diabetic participants and extended these findings to glucose-intolerant participants. Our findings suggest that modifying the speed of eating may be helpful in reducing body weight in those who are recommended weight loss [5, 6].

The mechanisms underlying the association between fast eating and obesity and cardiovascular risk factors are not fully understood. In general, persons who eat quickly are thought to consume too much energy before recognising satiety, since satiety signals transmitted to the brain are triggered by nutrient ingestion, gastric distension and the release of gut factors, including cholecystokinin [21]. A

previous study demonstrated that eating quickly leads to lower postprandial concentrations of anorexigenic gut peptides such as peptide YY and glucagon-like peptide (GLP)-1 [22]. Another study showed that eating slowly decreased energy intake and resulted in more satiety after meal completion [23]. The present study did not show a significant positive association between eating rate and total energy intake, although the highest total energy intake was observed in very fast eaters. This is probably due to under-reporting of energy intake by obese persons, as shown in previous studies [24–26]. Some epidemiological studies, including the current study, have demonstrated that eating

Table 3 Multivariate-adjusted ORs for obesity and cardiovascular risk factors according to eating rate category and glucose tolerance status

Variable	Glucose tolerance status	Eating rate category				<i>p</i> for trend
		Slow	Medium	Relatively fast	Very fast	
Obesity	Normal glucose	1 (referent)	1.38 (0.90, 2.10)	2.16 (1.37, 3.40)	3.62 (1.98, 6.61)	<0.001
	IFG	1 (referent)	1.08 (0.73, 1.61)	1.42 (0.92, 2.20)	2.83 (1.64, 4.88)	<0.001
	Diabetes	1 (referent)	1.21 (1.00, 1.46)	1.44 (1.19, 1.75)	2.06 (1.65, 2.58)	<0.001
Elevated waist circumference	Normal glucose	1 (referent)	1.44 (1.07, 1.95)	2.30 (1.62, 3.27)	3.31 (1.90, 5.76)	<0.001
	IFG	1 (referent)	1.97 (1.33, 2.92)	1.84 (1.19, 2.86)	4.10 (2.29, 7.34)	<0.001
	Diabetes	1 (referent)	0.89 (0.75, 1.07)	1.06 (0.88, 1.28)	1.55 (1.24, 1.94)	<0.001
Elevated blood pressure	Normal glucose	1 (referent)	1.01 (0.74, 1.37)	1.31 (0.93, 1.86)	0.79 (0.46, 1.35)	0.49
	IFG	1 (referent)	1.28 (0.86, 1.90)	1.60 (1.02, 2.51)	2.32 (1.24, 4.34)	0.004
	Diabetes	1 (referent)	1.17 (0.97, 1.42)	1.07 (0.88, 1.30)	1.56 (1.22, 2.00)	0.01
Elevated triacylglycerol	Normal glucose	1 (referent)	1.10 (0.74, 1.63)	1.29 (0.84, 2.00)	1.84 (0.99, 3.39)	0.046
	IFG	1 (referent)	1.03 (0.69, 1.54)	1.14 (0.73, 1.78)	1.23 (0.70, 2.18)	0.38
	Diabetes	1 (referent)	0.96 (0.80, 1.16)	0.89 (0.73, 1.08)	0.99 (0.79, 1.25)	0.58
Reduced HDL-cholesterol	Normal glucose	1 (referent)	1.01 (0.65, 1.58)	1.39 (0.85, 2.27)	1.44 (0.69, 2.99)	0.11
	IFG	1 (referent)	1.10 (0.65, 1.85)	1.48 (0.84, 2.62)	1.47 (0.71, 3.06)	0.12
	Diabetes	1 (referent)	0.97 (0.78, 1.20)	0.98 (0.79, 1.22)	1.18 (0.91, 1.53)	0.29

Numbers in parentheses represent 95% CIs

Multivariate adjustment was made for age, sex, total energy intake, dietary fibre intake, current smoking habits, current drinking habits and regular exercise habits

quickly significantly increases obesity, even after adjustment for total energy intake [9–11]. This raises the possibility that other mechanisms independently of total energy intake may underlie the association between eating rate and excessive body weight.

Decreased mastication in fast eaters and subsequent inactivation of neuronal histamine may be related to weight gain. Mastication-induced activation of histamine neurons suppresses physiological food intake through H₁-receptors in the hypothalamic paraventricular nucleus and the ventromedial hypothalamic nucleus, known as satiety centres [27]. In addition, histamine neuron activation increases energy expenditure by upregulating gene expression of the uncoupling protein family through the sympathetic efferent nerve, leading to accelerated lipolysis, particularly in visceral adipose tissue, in rats [27].

In contrast to that demonstrated in obesity, few studies have provided evidence of associations between eating rate and glycaemic levels. One cross-sectional study showed an association between eating rapidly and hyperglycaemia (FPG \geq 5.6 mmol/l) in individuals who underwent health examinations, although no adjustment was made for dietary factors in this study [12]. Another prospective study of a relatively small number of individuals revealed a significant influence of self-reported fast eating on future development of impaired glucose tolerance [14]. A cross-sectional study conducted among 426 Japanese diabetic patients indicated that rapid eating was significantly associated with BMI but

not with HbA_{1c} levels [28]. To date, no studies have examined either FPG or HbA_{1c} levels simultaneously among individuals including diabetic patients. In the current study, HbA_{1c} levels increased significantly in association with increases in eating rate in the diabetic patients receiving insulin therapy. This relationship remained significant after further adjustment for BMI in addition to other confounding factors. However, such an association was not observed for FPG. These findings may imply that eating quickly increases HbA_{1c} levels by increasing postprandial plasma glucose levels. In addition, the effects of eating quickly on blunted postprandial GLP-1 responses [22] and insulin resistance [29, 30] may fail to compensate for the increased postprandial glucose levels induced by eating quickly.

Our study has several strengths. First, it consisted of participants with a wide range of glucose tolerance status, from normal fasting glucose levels to type 2 diabetes requiring insulin therapy. Therefore, the present results may be highly generalisable to clinical settings. Second, we took into consideration various confounding factors, including diet and other lifestyle factors. However, some limitations should be discussed. First, we evaluated eating rate with self-reported questionnaires, as used in previous studies [9–11, 28, 30]. However, one of our co-authors has reported a high level of concordance between self-reported and friend-reported eating rate [9]. Furthermore, our preliminary study also assessed the validity of this eating rate questionnaire by comparing it with actual meal duration among 48

type 2 diabetic outpatients (age 68 ± 10 [SD] years; 19 males, 29 females). The age- and sex-adjusted meal duration was 26.1 ± 1.9 (SE) min in the slow eaters ($n=11$), 23.7 ± 1.8 min in the medium eaters ($n=12$), 18.4 ± 1.6 min in the relatively fast eaters ($n=14$) and 16.8 ± 1.9 min in the very fast eaters ($n=11$) (p for trend <0.001). In addition, the definition of glucose tolerance status was based on the FPG level only. In the present study, a positive association between eating rate and glycaemia was observed only in the diabetic patients on insulin therapy. Therefore, the results would not substantially change by using oral glucose tolerance tests to define glucose tolerance status instead of FPG only. Furthermore, we cannot prove any cause-and-effect relationships because of the cross-sectional design of our study. Finally, there may be other confounding factors besides those evaluated in the present study.

In conclusion, the present study clearly showed a positive association between eating quickly and obesity, irrespective of glucose tolerance status. A relationship with cardiovascular risk factors was also observed. In addition, a positive association between speed of eating and HbA_{1c} level was demonstrated in diabetic patients treated with insulin; however, this was not seen in those who were not treated with insulin. We consider that slowing down the speed of eating may therefore play an important role in the management of cardiovascular risk factors and diabetes in clinical settings.

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Contribution statement TO, HF, MI and YKiy were responsible for the study concept and design. TO and MI conducted the analyses, and HF, YKik, SO, YI, HI, YD, YH, NM, TN, KU, UN, SS, YKiy and TK helped with interpreting the data and contributed to the discussion. TO and MI drafted the manuscript. All authors participated in revising the manuscript critically and approved the final version.

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