

# Association Between Self-Reported Chewing Status and Glycemic Control in Japanese Adults

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## Research Article

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# Abstract

This cross-sectional study investigated the relationship between self-reported chewing status and glycemic control in 32,137 Japanese adults who participated in health checkups. Chewing status was evaluated using a self-reported questionnaire. We defined poor glycemic control as a hemoglobin A1c (HbA1c) level  $\geq 6.5\%$  or the use of medication to control diabetes; 1,891 (5.9%) respondents met these criteria. After adjusting for gender, age, smoking status, exercise habits, body mass index, and eating speed, poor glycemic control was found to be positively associated with male gender (odds ratio [OR], 2.142; 95% confidence interval [CI], 1.903 to 2.411;  $p < 0.001$ ), older age (OR, 1.093; 95% CI, 1.087 to 1.099;  $p < 0.001$ ), higher body mass index (OR, 1.234; 95% CI, 1.219 to 1.249;  $p < 0.001$ ), current smoker status (OR, 1.378; 95% CI, 1.223 to 1.552;  $p < 0.001$ ), and ability to chew well (OR, 0.795; 95% CI, 0.699 to 0.904;  $p < 0.001$ ). Furthermore, a negative association was found between the ability to chew well and poor glycemic control in those  $\geq 40$  years of age, but not in those between 20 and 39 years of age. In conclusion, self-reported ability to chew well was associated with poor glycemic control in Japanese adults aged  $\geq 40$  years.

## Introduction

Diabetes is a lifestyle-related disease characterized by high blood sugar levels, and it leads to complications, such as neuropathy, retinopathy, and nephropathy<sup>1</sup>. The prevalence of diabetes continues to increase worldwide; in 2017, approximately 451 million people worldwide had diabetes, and the number is expected to reach 693 million by 2045<sup>2</sup>. According to the 2019 National Health and Nutrition Survey<sup>3</sup> in Japan, about 20% of men and 11% of women have or are likely to have diabetes, and the public health implications are enormous.

Hemoglobin A1c (HbA1c) serves as a biomarker for testing and monitoring diabetes, because it reflects changes in blood glucose levels<sup>4</sup>, and it can be applied to guide strategies for diabetes treatment and to control and predict the risk of progressive complications of diabetes<sup>5</sup>. Hence, the monitoring of HbA1c is important for the development of appropriate strategies to prevent diabetes and its associated complications.

Some studies have reported relationships between oral conditions and glycemic control. For instance, it has been revealed that the periodontal status<sup>6,7</sup> and the number of decayed teeth<sup>8</sup> were closely associated with the HbA1c levels. Since the periodontal status is related to masticatory performance<sup>9</sup>, it is likely that the chewing status is also associated with HbA1c levels. For instance, a clinical study reported that insufficient chewing ability was more frequently seen in subjects with a HbA1c level  $\geq 7\%$  than in those with a level  $< 7\%$ <sup>10</sup>. However, since very little information is available on the relationship between chewing status and glycemic control in humans, additional clinical work is needed.

In Japan, the Ministry of Health, Labor and Welfare has mandated that medical insurers must require insured persons 40 to 74 years of age to undergo specific health checkups focused on metabolic

diseases, including diabetes mellitus. Unfortunately, the specific medical checkups do not currently include a dental checkup. However, among the questionnaires used in the specific health checkups, an item on chewing status was added in 2018. If the self-reported chewing status is related to the glycemic status, the self-reported chewing status from the specific health checkups may have implications on the health guidance, especially guidance for oral health care, that should be provided to individuals after the specific health checkups. The present study examined whether the self-reported chewing status is associated with glycemic control in a Japanese population that underwent regular health checkups.

## Results

The prevalence of poor glycemic control was 5.9% (Table 1). Respondents with poor glycemic control were significantly more likely to be male ( $p < 0.001$ ), be older ( $p < 0.001$ ), have a higher body mass index (BMI;  $p < 0.001$ ), be a current smoker ( $p < 0.001$ ), exercise regularly ( $p < 0.001$ ), eat quickly ( $p < 0.001$ ), and have a low ability to chew well ( $p < 0.001$ ).

Table 2 shows the results of univariate logistic regression analysis with poor glycemic control as the dependent variable in all participants. The results showed that the odds ratio (OR) for poor glycemic control was higher among those who were male (OR, 3.104; 95% confidence interval [CI], 2.782 to 3.462), were older (OR, 1.081; 95% CI, 1.076 to 1.087), had a higher BMI (OR, 1.224; 95% CI, 1.211 to 1.237), had regular exercise habits (OR, 1.275; 95% CI, 1.149 to 1.414), and ate quickly (OR, 1.307; 95% CI, 1.190 to 1.435) than among those who did not. The results also showed that the OR for poor glycemic control was lower among those who had the ability to chew well (OR, 0.615; 95% CI, 0.545 to 0.693) than among those who did not.

Table 3 shows the results of the multivariate adjusted logistic regression analysis with poor glycemic control as the dependent variable in all participants. Poor glycemic control was significantly associated with male gender (OR, 2.843; 95% CI, 2.534 to 3.189), older age (OR, 1.087; 95% CI, 1.081 to 1.093), current smoker status (OR, 1.374; 95% CI, 1.224 to 1.541), the presence of regular exercise habits (OR, 0.855; 95% CI, 0.766 to 0.955), the ability to chew well (OR, 0.810; 95% CI, 0.715 to 0.918), and a fast eating speed (OR, 1.338; 95% CI, 1.214 to 1.552) after adjusting for gender, age, smoking status, regular exercise habits, eating speed, and chewing status. After additional adjustments for the BMI, poor glycemic control was significantly associated with male gender (OR, 2.142; 95% CI, 1.903 to 2.411), older age (OR, 1.093; 95% CI, 1.087 to 1.099), higher BMI (OR, 1.234; 95% CI, 1.219 to 1.249), current smoker status (OR, 1.378; 95% CI, 1.223 to 1.552), and the ability to chew well (OR, 0.795; 95% CI, 0.699 to 0.904).

The numbers of participants with poor glycemic control were 31 (1.0%) in the 20-to-39-year-old group, 1,498 (5.6%) in the 40-to-64-year-old group, 362 (14.9%) in the  $\geq 65$ -year-old group, and 1,891 (5.9%) in total among all participants (Table 4). The numbers of participants who reported having the ability to chew well were 2,826 (90.8%) in the 20-to-39-year-old group, 23,145 (87.1%) in the 40-to-64-year-old group, 1,974 (81.0%) in the  $\geq 65$ -year-old group, and 27,945 (87.0%) in total among all participants. There

were significant differences in the prevalence of poor glycemic control and chewing well among the different age groups ( $p < 0.001$ ).

Table 5 shows the results of the multivariate adjusted logistic regression analysis with poor glycemic control as the dependent variable in different age groups. In the 20-to-39-year-old group, poor glycemic control was significantly associated with older age (OR, 1.208; 95% CI, 1.051 to 1.389) and higher BMI (OR, 1.319; 95% CI, 1.238 to 1.406) after adjusting for gender, age, smoking status, regular exercise habits, eating speed, and chewing status. In the 40-to-64-year-old group, poor glycemic control was significantly associated with male gender (OR, 2.304; 95% CI, 2.009 to 2.643), older age (OR, 1.102; 95% CI, 1.093 to 1.112), higher BMI (OR, 1.241; 95% CI, 1.225 to 1.257), current smoker status (OR, 1.369; 95% CI, 1.204 to 1.557), and the ability to chew well (OR, 0.848; 95% CI, 0.732 to 0.983). Furthermore, in the  $\geq 65$ -year-old group, poor glycemic control was also significantly associated with male gender (OR, 1.593; 95% CI, 1.246 to 2.036), older age (OR, 1.058; 95% CI, 1.018 to 1.100), higher BMI (OR, 1.156; 95% CI, 1.117 to 1.197), and the ability to chew well (OR, 0.655; 95% CI, 0.499 to 0.859).

## Discussion

To the best of our knowledge, this is the first investigation of the association between self-reported chewing status and glycemic control among Japanese adults. We found that self-reported ability to chew well was negatively associated with poor glycemic control after adjusting for the potential confounding variables of gender, age, BMI, smoking status, regular exercise habits, eating speed, and chewing status. The results indicated that maintaining the ability to chew well could contribute to better glycemic control. In Japan, there are no mandatory dental health checkups for adults. However, in the questionnaires used for the specific health checkups required for health insurance, there is an item on chewing status. This item on chewing status may be applied to screen for individuals who may need dental intervention for controlling blood sugar levels.

In this study, a negative relationship between self-reported ability to chew well and poor glycemic control was found among participants in the 40-to-64-year-old group and the  $\geq 65$ -year-old group. However, there was no association between the ability to chew well and poor glycemic control among the participants in the 20-to-39-year-old group. These results suggested that the association between the self-reported chewing status and glycemic control is seen only in those who are  $\geq 40$  years of age. In our observations, the prevalence of participants with poor glycemic control was only 1.0% in the 20-to-39-year-old group. In young populations, the number of participants with poor glycemic control may be too small to show a significant association between the self-reported chewing status and glycemic control.

There are several possible mechanisms for the relationship between the chewing status and glycemic control. Chewing breaks down big food particles into small pieces, and this increases its digestibility by increasing the surface area for various enzymes to act on<sup>11</sup>. This helps to stimulate the cephalic phase of insulin secretion and incretin release from the gut to promote the absorption of glucose<sup>11</sup>. It is also known that chewing can attenuate decreases in the concentration of glucagon-like peptide-1<sup>12</sup>, which

contributes to regulating glucose-stimulated insulin secretion<sup>13</sup>. As such, chewing is likely to regulate blood glucose levels through the secretion of insulin and incretin. However, because we did not measure the blood levels of insulin and incretin in this study, further studies are needed to clarify the mechanisms by which chewing status affects glycemic control.

Previous studies have investigated the relationship between oral health and glycemic control. It is well known that periodontal disease can promote diabetes, because local inflammation is involved in the development of insulin resistance, which leads to poor glycemic control<sup>14</sup>. It is also accepted that dental caries is a risk factor for poor glycemic control<sup>8</sup>. Furthermore, it has been shown that the number of missing teeth is positively associated with a poorer general health status, including higher fasting plasma glucose levels<sup>15</sup>. In our observations, there was a negative association between the ability to chew well and poor glycemic control. The previous findings and our present findings support the notion that the prevention of oral diseases and the maintenance of oral functions are important for maintaining healthy glycemic control.

In this study, poor glycemic control was associated with aging and current smoking. These observations are consistent with previously reported findings demonstrating that aging<sup>16</sup> and smoking<sup>17, 18</sup> are risk factors for diabetes. In addition, our results showed that a higher BMI was associated with poor glycemic control. This observation is also in agreement with the findings of a previous study, which reported that an increased BMI above the normal weight levels was associated with an increased risk of being diagnosed with a complication resulting from diabetes<sup>19</sup>.

We also found that after adjusting for gender, age, smoking status, regular exercise habits, eating speed, and chewing status in all participants, poor glycemic control was negatively associated with the presence of regular exercise habits, and positively associated with eating quickly. However, these associations disappeared after further adjustment for the BMI. This indicated that the BMI overwhelmed the effects of regular exercise habits and eating speed on glycemic control. Since it has been reported that exercise<sup>20</sup> and eating speed<sup>21</sup> are closely correlated with the BMI, regular exercise habits and eating speed are thought to indirectly influence glycemic control by affecting the BMI.

In the present study, the prevalence of poor glycemic control and the ability to chew well was 5.9% and 87.0%, respectively. From the data of the National Health and Nutrition Survey, the prevalence of poor glycemic control and the ability to chew well was 14.5% and 75.0%, respectively, in 2019<sup>3</sup>. This indicated that the prevalence of poor glycemic control in our study was low while that of the ability to chew well was high when compared to the Japanese national data. The reason for these differences may be because our study was conducted among people who participated in medical checkups, suggesting that they may be more conscious of their health than those who do not participate in medical checkups. This may limit the extrapolation of our findings to the general population.

The present study also has other limitations. For instance, the current study was a cross-sectional study, so it cannot demonstrate causal relationships. Additional longitudinal studies are needed to investigate

the relationship between chewing status and glycemic control. In addition, we should examine actual chewing times and bite forces for judging the chewing status in the future. On the other hand, a strength of this study is the sufficient sample size for assessing the prevalence of poor glycemic control among participants with different chewing statuses. Furthermore, we were able to gather study population data from multiple locations (Gifu and Okayama).

In conclusion, in the present population, poor glycemic control was negatively associated with the self-reported ability to chew well, and was positively associated with male gender, older age, a higher BMI, and current smoker status. In addition, a negative association between the self-reported ability to chew well and poor glycemic control was found among those who were  $\geq 40$  years of age, but not in those who were 20 to 39 years old.

## Methods

### Participants.

We analyzed data from community residents who participated in health checkups at Asahi University Hospital in Gifu, Japan, and at the Junpukai Health Maintenance Center in Okayama, Japan. A total of 35,571 Japanese adults aged  $\geq 20$  years participated in the baseline survey between April 2018 and March 2019. We excluded 3,434 residents due to missing data on the HbA1c level and/or chewing status. In total, we analyzed data from 32,137 community residents in this study. This study was approved by the Ethics Committee of Asahi University (No. 27010), and was performed in accordance with the Declaration of Helsinki. All residents who participated provided written informed consent.

### Measurement of HbA1c.

The measurement of HbA1c levels was done using high-performance liquid chromatography with venous blood samples collected after an overnight fast<sup>22</sup>.

### Evaluation of glycemic control.

In general, a HbA1c level  $\geq 6.5\%$  indicates poor glycemic control<sup>23</sup>. Therefore, the participants who had a HbA1c level  $\geq 6.5\%$  were defined as having poor glycemic control. In addition, participants who were using medication for diabetes were also included in the group with poor glycemic control since they had previously been diagnosed with diabetes already<sup>24</sup>.

### Assessment of body composition.

The height and body weight were measured, and the BMI was calculated as the weight (kg) divided by the height squared ( $m^2$ ).

### Questionnaire.

We used the same questionnaire that is used in medical checkups in Japan. The questionnaire items included age, gender, current smoking status (yes/no), regular exercise habits (absence/presence), physical activity (low/high), adequate sleep (yes/no), alcohol consumption (not daily/daily), eating speed (slowly, medium, or quickly), and chewing status (“I can eat anything,” “Sometimes it is difficult to chew due to dental problems, such as dental caries and periodontal disease,” or “I can hardly chew.”)<sup>25</sup>. Respondents who answered “I can eat anything” were considered to have the ability to chew well. Logistic analysis in our preliminary study of 763 volunteers identified that the ability to chew well was associated with being treated at a dental clinic (OR, 0.441;  $p < 0.01$ ), the number of teeth present (OR, 1.090;  $p < 0.05$ ), and the number of decayed, missing, or filled teeth (OR, 0.957;  $p < 0.05$ ) after adjusting for age, gender, smoking status, being treated at a dental clinic, frequency of tooth brushing, number of teeth present, number of decayed, missing, or filled teeth, and presence or absence of a probing pocket depth of  $\geq 4$  mm.

### **Statistical analysis.**

Continuous variables are expressed as medians (first and third quartiles). Significant differences in characteristics between the study participants with and without poor glycemic control were assessed using the chi-squared and Mann-Whitney U tests. Differences in the prevalence of poor glycemic control and the ability to chew well among different age groups (20 to 39, 40 to 64, and  $>65$  years of age) were assessed using the chi-squared test. Univariate and multivariate stepwise logistic regression analyses were performed with the presence and absence of poor glycemic control as dependent variables. The third category of variables concerned the sample (age, gender, and BMI) and different variables related to glycemic control (exercise habits, smoking habits, drinking habits, and eating speed), and these variables were adjusted for in these analyses. Variables with a  $p < 0.10$  were removed from the model while those with a  $p < 0.05$  were included. Independent variables with a  $p < 0.05$  in the univariate model were selected. All data were analyzed using SPSS statistics version 25 (IBM Japan, Tokyo, Japan). All  $p$  values  $< 0.05$  were considered to be statistically significant.

## **Declarations**

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### **Author contributions**

K. I., T. A., T. Y., and T. T. conceived and planned the project. K. I., D. E., K. W., A. O., F. D., and T. K. performed data entry. K. I., and T. T. wrote the body of the manuscript. K. I., M. M., and T. T. conducted statistical analysis. T. T. organized and supervised the study. All authors reviewed the manuscript.

### **Competing interests:**

The authors have no competing interests to declare.

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## Tables

**Table 1.** Characteristics of the study populations with and without poor glycemic control.

Variables	Poor glycemic control		p value	
	No (n=30,246)	Yes (n=1,891)		
Men (%)	15671 (51.8)	1455 (76.9)	<0.001	
Age (years)	49 (43, 56)	57 (51, 63)	<0.001	
BMI (kg/m <sup>2</sup> )	22.4 (20.3, 24.7)	25.7 (23.3, 28.6)	<0.001	
Current smoker	Yes (%)	5471 (18.1)	491 (26.0)	<0.001
Regular exercise habits	Presence (%)	7035 (23.3)	527 (27.9)	<0.001
Physical activity	High (%)	7962 (26.3)	506 (26.8)	0.688
Sleeping well	Yes (%)	18946 (62.6)	1189 (62.9)	0.844
Alcohol drinking	Everyday (%)	7604 (25.1)	487 (25.8)	0.549
Eating speed	Quickly (%)	11281 (37.3)	827 (43.7)	<0.001
Chewing status	Well (%)	26415 (87.3)	1530 (80.9)	<0.001
Abbreviations: BMI, body mass index.				

**Table 2.** Crude odds ratios and 95% CI for poor glycemic control according to the analyzed factors in all participants.

Variables		Crude ORs	95% CI	p value
Gender	Women	1	(reference)	<0.001
	Men	3.104	2.782-3.462	
Age (years)		1.081	1.076-1.087	<0.001
BMI (kg/m <sup>2</sup> )		1.224	1.211-1.237	<0.001
Current smoker	No	1	(reference)	<0.001
	Yes	1.588	1.427-1.767	
Regular exercise habits	Absence	1	(reference)	<0.001
	Presence	1.275	1.149-1.414	
Physical activity	Low	1	(reference)	0.678
	High	1.022	0.921-1.136	
Sleeping well	No	1	(reference)	0.836
	Yes	1.010	0.918-1.112	
Alcohol drinking	Not everyday	1	(reference)	0.551
	Everyday	1.033	0.929-1.149	
Eating speed	Not quickly	1	(reference)	<0.001
	Quickly	1.307	1.190-1.435	
Chewing well	No	1	(reference)	<0.001
	Yes	0.615	0.545-0.693	
Abbreviations: ORs, odds ratios; CI, confidence interval; BMI, body mass index.				

**Table 3.** Adjusted odds ratios and 95% CI for poor glycemic control according to the analyzed factors in all participants.

Variables		Crude ORs	95% CI	p value
Model 1				
Gender	Women	1	(reference)	<0.001
	Men	2.843	2.534-3.189	
Age (years)		1.087	1.081-1.093	<0.001
Current smoker	No	1	(reference)	<0.001
	Yes	1.374	1.224-1.541	
Regular exercise habits	Absence	1	(reference)	0.005
	Presence	0.855	0.766-0.955	
Eating speed	Not quickly	1	(reference)	<0.001
	Quickly	1.338	1.214-1.476	
Chewing well	No	1	(reference)	0.001
	Yes	0.810	0.715-0.918	
Model 2				
Gender	Women	1	(reference)	<0.001
	Men	2.142	1.903-2.411	
Age (years)		1.093	1.087-1.099	<0.001
BMI (kg/m <sup>2</sup> )		1.234	1.219-1.249	<0.001
Current smoker	No	1	(reference)	<0.001
	Yes	1.378	1.223-1.552	
Chewing well	No	1	(reference)	<0.001
	Yes	0.795	0.699-0.904	
Abbreviations: ORs, odds ratios; CI, confidence interval; BMI, body mass index.				
Model 1: Adjusting gender, age, smoking status, exercise habits, eating speed, and chewing status.				
Model 2: Adjusting gender, age, BMI, smoking status, exercise habits, eating speed and chewing status.				

**Table 4.** Numbers of participants with poor glycemic control and chewing well.

Variables		20-39 years	40-64 years	65≥ years	Total
Poor glyceimic control	No	3,082	25,090	2,074	30,246
	Yes	31	1,498	362	1,891
Chewing well	No	287	3,443	462	4,192
	Yes	2,826	23,145	1,974	27,945

**Table 5.** Adjusted odds ratios and 95% CI for poor glyceimic control according to the analyzed factors in different age groups.

Variables		Adjusted ORs	95% CI	p value
20-39 years (n= 3,113)				
Gender	Women	1	(reference)	0.071
	Men	2.553	0.922-7.074	
Age (years)		1.208	1.051-1.389	0.008
BMI (kg/m <sup>2</sup> )		1.319	1.238-1.406	<0.001
40-64 years (n= 26,588)				
Gender	Women	1	(reference)	<0.001
	Men	2.304	2.009-2.643	
Age (years)		1.102	1.093-1.112	<0.001
BMI (kg/m <sup>2</sup> )		1.241	1.225-1.257	<0.001
Current smoker	No	1	(reference)	<0.001
	Yes	1.369	1.204-1.557	
Chewing well	No	1	(reference)	0.029
	Yes	0.848	0.732-0.983	
65≥ years (n= 2,436)				
Gender	Women	1	(reference)	<0.001
	Men	1.593	1.246-2.036	
Age (years)		1.058	1.018-1.100	0.005
BMI		1.156	1.117-1.197	<0.001
Current smoker	No	1	(reference)	0.053
	Yes	1.411	0.969-1.591	
Eating speed	Not quickly	1	(reference)	0.087
	Quickly	1.242	0.969-1.591	
Chewing well	No	1	(reference)	0.002
	Yes	0.655	0.499-0.859	
Abbreviations: ORs, odds ratios; CI, confidence interval; BMI, body mass index.				
Adjusting gender, age, BMI, smoking status, exercise habits, eating speed and chewing status.				