Dental, Oral and Craniofacial Research

Research Article ISSN: 2058-5314

# The effect on plasma insulin secretion from different amounts of chewing ~ differences in chewing a mouthful for 20 or 40 times~

**Hideto Matsuda[1]*, Aya Uchida[1], Kazuyoshi Hashimoto[2] and Kazuo Takada[3]**

[1]Department of Food and Nutrition, College of Nagoya Bunri University, 2-1, Sasazuka-Cho, Nagoya Nishi-Ku, Aichi, Japan

[2]Department of Fixed Prosthodontics, Aichi-Gakuin University School of Dentistry, 2-11, Suemori-Douri, Nagoya Chikusa-ku, Aichi, Japan

[3]Department of Health and Nutrition, Faculty of Health and Human life, Nagoya Bunri University, 365, Maeda, Inazawa-Cho, Inazawa City, Aichi, Japan

## Abstract

**Aim:** Insulin is an important excretion for regulating blood glucose levels. We conducted this research given the little data on varying the number of times a given food product is chewed regarding blood glucose regulation of insulin after meals.

**Method:** 16 healthy 19-20 years old females participated. They were given a rice ball to eat by chewing either 20 or 40 times per mouthful and their blood glucose levels and IRI levels after eating were compared.

**Results:** No difference was found in blood glucose levels. IRI was significantly lower 60 min after eating when each mouthful was chewed 40 times, however no difference was found for total insulin secretion. Consideration: By chewing each mouthful 40 times, intraoral sensory stimulation is increased, which is thought to increase IRI in the initial stage.

**Conclusion:** Increased chewing led to a change in insulin secretion, so increasing the amount of chewing can be expected to prevent lifestyle related diseases.

## Introduction

For better digestion, the activity of thoroughly chewing food and eating slowly is known as Fletchrism, after the American nutritionist, Horace Fletcher (1849-1919). He solved obesity without overeating by thoroughly chewing [1]. The endocrine substance that plays the important role in blood glucose regulation is insulin. The most biologically important substances for controlling insulin are blood glucose and incretin. Incretin is produced in the digestive tract, and accelerates insulin secretion from pancreatic B-cells following a rise in blood glucose levels [2]. There are 2 forms on insulin secretion. The first is known as the cephalic phase, wherein before food is absorbed, intraoral sensory stimulation from food causes the vagus nerve to react and secretion occurs within a few minutes of ingestion [3-5]. This secretion is unrelated to glucose or amino acid concentrations in the blood [5,6]. The other is known as the gastrointestinal phase, wherein reaction occurs after food absorption, this is a reaction involved in regulating blood glucose levels after eating. There are few reports on insulin regulating blood glucose levels after eating by comparing blood glucose and insulin secretion after eating by varying the amount of chewing of a given food [7,8]. From this background, we compared IRI secretion after eating when changing the amount of chewing for a traditional Japanese food, the "rice ball."

## Participants and method

### Participants

Table 1 shows data for the participants. The participants were 16 females aged between 19-20 years old (average age: 19.3 ± 0.6 years) and had no physical abnormalities. This research was implemented based on the Helsinki Declaration, and with the approval of the Nagoya Bunri University Ethics Committee (No. 35). The research was initiated after explaining the aims to the participants and with their understanding and consent.

### Physical measurements

A height meter (YAGAMI, YL-65S) was used to measure the participant's height and a body fat meter (TANITA BODY ANALYZER TBF350) was used to measure their weight.

### Feeding the participants

2 rice balls (Kelp, made by Warabeya Tokai (Nisshin, Aichi Prefecture) (E 342 kcal, P 6.6 g, F 1.0 g, C 76.4 g) 75.8 g) were used. The participants were randomly separated into 2 groups, where one group chewed 20 times to represent normal chewing, and the other group chewed 40 times. The participants ate in time to a metronome

***Correspondence to:*** Hideto Matsuda, Department of Food and Nutrition, College of Nagoya Bunri University, 2-1, Sasazuka-Cho, Nagoya Nishi-Ku, Aichi, Japan, E-mail: hideto4808758@yahoo.co.jp; matsuda.hideto@nagoya-bunri.ac.jp

***Key words:*** *chewing a mouthful, plasma insulin, blood glucose, rice ball*

**Special Issue: Research on human food, chewing and swallowing**

Shigeru Watanabe, DDS, PhD

Professor of Division of Pediatric Dentistry,

School of Dentistry, Meikai University, Japan

Published: August 31, 2017

**Table 1.** Clinical characteristics of the 16 subjects.

| | |
|---|---|
| n (male/female) | 16(0/16) |
| Age (years) | 19.3±0.6 |
| Body height (cm) | 156.2±3.4 |
| Body weight (kg) | 47.1±4.8 |
| Body Mass Index (kg/m$^2$) | 19.3±1.5 |
| Body fat (%) | 21.9±3.1 |
| Fasting Plasma Glucose (FPG) (mg/dL) | 84±6 |
| Fasting immunoreactive insulin (F-IRI) (μU/mL) | 6.9±1.8 |
| Homeostatic model assessment of insulin resistance (HOMA-R) | 1.4±0.4 |

The data are expressed as the mean ± standard deviation (SD).

at a rhythm of one chew per second. To regulate feeding time, the food products were eaten over a period of 15 minutes, and this was repeated 1 week later.

### Implementation method

**Blood sampling:** No food was allowed after the previous evening meal, and blood was sampled at 9am the next morning to set the Fasting plasma glucose (FPG) and Fasting immunoreactive insulin (F-IRI). Blood was taken from the median cubital vein 5 times: on fasting and then 15, 30, 60 and 120 minutes after eating the subject food.

**Blood biochemical examination:** The hexokinase G-6-PDH method was used to measure blood glucose (BS) and the RIA solid phase method was used to measure Immuno Reactive Insulin (IRI).

Area under the curve (AUC) of blood glucose and overall insulin values were calculated.

Calculated from the total area of the shape (trapezoid) drawn by the BS or IRI against time (hrs) graphs.

Calculating HOMA-R (homeostasis model assessment for insulin resistance)

In order to detect insulin resistance, HOMA-R was calculated using the equation below, where a value over 2.5 was interpreted as a high insulin resistance 9).

HOMA-R＝FPG(mg/dL)×F-IRI(μU/mL)/405

**Measuring the number of chews:** Each participant counted the number of times they chewed themselves.

Statistical analysis and verification used the Wilcoxon signed rank test in SPSS statistics ver.21 statistical software (IBM), with a significance level of 5%. A 2-sided test was run.

## Results

### Participants

The participants Body Mass Index (BMI) was 19.3 ± 1.5 kg/m$^2$, and body fat was less than 30% (21.9 ± 3.1%) for all participants, implying none of them were obese. All participants had an FPG of less than 110 mg/dL (84 ± 6 mg/dL), an F-IRI of less than 10 μU/mL (6.9 ± 1.8 μU/mL), and a HOMA-R of less than 2.5 (1.4 ± 0.4). Therefore, none of the participants had an impaired glucose tolerance.

### Total number of chews

For 20 chews, the total was 881 ± 168 times, and for 40 chews it was 1070 ± 189, showing a significant difference (p=0.0005).

### Blood glucose levels

Blood glucose is shown in Table 2. A significant difference is not seen between both groups.

### IRI values

IRI values are shown in Table 3. At 60 min after eating, the 20 chews/mouthful was 46.0 ± 15.6 μU/mL, and the 40 chews/mouthful was 39.0 ± 16.6 μU/mL, showing a significant difference (p=0.0437).

## Considerations

Chewing is the first process in digesting food. Chewing reduces the size of food morsels, increasing the surface area, making it easier for gastric acids to take effect. Read, *et al.* [7] reported that blood glucose after eating was significantly higher for thorough chewing compared with swallowing without chewing for 4 foods, sweetcorn, white rice, diced apple and potato, in a group of 8 females and 4 males aged between 19 and 23. Since IRI was not measured, changes to insulin after eating was unclear, however blood glucose was considered to have increased, due to gastric acids thoroughly acting on the food that was broken down from chewing. Suzuki, *et al.* [8], reported that for a group of 16 non-obese people, tested to have normal glucose tolerance, fed a hamburger (130g, 230 kcal) and rice (100g, 155 kcal), results for normal chewing (10 times) and thorough chewing (30 times), resulted in significantly reduced blood glucose 90 min and 120 min after eating for the thorough chewing group and total insulin secretion was significantly smaller ($p<0.05$). As a result of increased digestive absorption due to thorough chewing, glucose 90 min after eating was lower. A reduced total insulin secretion is considered to be from accelerated insulin secretion in the initial stage of feeding due to thorough chewing [9]. Also, by increasing the amount of chewing, intraoral sensory stimulation from food increased, which affected IRI secretion after eating [10-12]. Our results also showed an effect on insulin secretion. By increasing the amount of chewing per mouthful, the total amount of chewing significantly increased, which in turn increased the intraoral sensory stimulation, which is thought to influence insulin secretion after eating. Fujise, *et al.* reported that when feeding rats hard foods and soft foods, both the meal size and meal duration increased in the soft food group more than the hard food group [13]. The stimulation of the muscle spindle of periodontal ligaments and masseter muscle is transmitted to the mesencephalic nucleus of the trigeminal nerve (Me5) and transmitted

**Table 2.** Blood glucose value after meal loading (mg/dL)

| Amount of chewing per mouthful | Fasting | After meal loading | | | | AUC |
|---|---|---|---|---|---|---|
| | | 15 min. | 30 min. | 60 min. | 120 min. | |
| 20 times | 84±6 | 116±15 | 108±21 | 97±16 | 85±10 | 195±24 |
| | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| 40 times | 84±6 | 112±18 | 101±22 | 93±22 | 86±14 | 189±33 |

AUC: mg*hr/dL
The data are expressed as the mean±SD. AUC indicates area under the curve.

**Table 3.** Plasma insulin value after meal loading (μU/mL)

| Amount of chewing per mouthful | Fasting | After meal loading | | | | Overall insulin value |
|---|---|---|---|---|---|---|
| | | 15 min. | 30 min. | 60 min. | 120 min. | |
| 20 times | 6.9±1.8 | 47.2±15.6 | 51.3±23.7 | 46.0±15.6 | 32.3±13.6 | 82.5±27.7 |
| | n.s. | n.s. | n.s. | * | n.s. | n.s. |
| 40 times | 6.9±2.3 | 48.5±18.2 | 47.4±15.0 | 39.0±16.6 | 29.8±13.1 | 74.9±25.0 |

Overall insulin value: μU*hr/mL, *: $p<0.05$,
The data are expressed as the mean±SD. Overall insulin value indicates area under the curve of plasma insulin. Area under the curve of plasma insulin response from 0 min to 120 min after meal loading.

to the histamine nerves. Histamine neurons regulate eating actions through neural projection in the feeding center and satiety center of the hypothalamus [14]. Both of them are in the upper centers of the sympathetic nervous system. However, the pancreas is controlled by both sympathetic and parasympathetic nerves [15]. Therefore, insulin secretion through these nerves is an extremely important factor [16,17]. The release of acetylcholine through the vagus nerve becomes more lively due to thorough chewing and as a result, insulin secretion increases in the initial stages after eating [8]. From the results of our research, although total insulin secretion did not change from chewing 40 times, insulin secretion 60 min after eating was significantly smaller. This is thought to be due to increased insulin secretion in the initial stages of feeding when chewing 40 times, rather than 20 times, which results in reduced insulin secretion 60 min after feeding.

Also, the effect of incretin is considered. Incretin is produced in the digestive tract and is secreted to match the rise in blood glucose due to the oral intake of nutrition; it activates pancreatic B-cells to accelerate insulin secretion. Moreover, insulin secretion accelerating actions are reported biologically, to be dependent on glucose concentration [18,19]. This time, although incretin was not measured, it is considered that digestion is accelerated by thorough chewing, which increases glucose concentration, and causes insulin secretion to accelerate. From these results, it is understood that increasing the amount of chewing influences IRI secretion and could be useful in preventing lifestyle related diseases.

## Conclusion

By chewing 40 times per mouthful, compared to 20 times, no difference was seen in blood glucose after eating however, IRI 60 min after eating was significantly smaller. Since no difference was seen in total insulin secretion, an increase in insulin secretion is considered to occur in the initial stages after eating, and can be expected to be effective in preventing lifestyle related diseases.

## Limitation

These results are from young female participants fed rice ball, and there is the possibility of obtaining different results by changing the participants and food.

## Conflicts of interest

There is no COI to disclose.

### References


1. Christen AG, Christen JA (1997) Horace Fletcher (1849-1919): "The Great Masticator". *J Hist Dent* 45: 95-100. [Crossref]
2. Ahren B, Holst JJ (2001) The cephalic insulin response to meal ingestion in humans is dependent on both cholinergic and noncholinergic mechanisms and is important for postprandial glycemia. *Diabetes* 50: 1030-1038. [Crossref]
3. Berthoud HR, Bereiter DA, Trimble ER, Siegel EG, Jeanrenaud B (1981) Cephalic phase, reflex insulin secretion. *Diabetologia* 20: 393-398. [Crossref]
4. Teff KL, Townsend RR (1999) Early phase insulin infusion and muscarinic blockade in obese and lean subjects. *Am J Physiol* 277: R198-208. [Crossref]
5. Strubbe JH, Steffens AB (1975) Rapid insulin release after ingestion of a meal in the unanesthetized rat. *Am J Physiol* 229: 1019-1022. [Crossref]
6. Teff KL, Levin BE, Engelman K (1993) Oral sensory stimulation in men: effects on insulin, C-peptide, and catecholamines. *Am J Physiol* 265: R1223-1230. [Crossref]
7. Read NW, Welch IM, Austen CJ, Barnish C, Bartlett CE, et al. (1986) Swallowing food without chewing; a simple way to reduce postprandial glycaemia. *Br J Nutr* 55: 43-47. [Crossref]
8. Suzuki H, Fukushima M, Okamoto S, Takahashi O, Shimbo T, et al. (2005) Effects of thorough mastication on postprandial plasma glucose concentrations in nonobese Japanese subjects. *Metabolism* 54: 1593-1599.
9. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC (1985) Homeostasis model assessment: insulin resistance and ß-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia* 28: 412-419.
10. Bellisle F, Louis-Sylvestre J, Demozay F, Blazy D, Le Magnen J (1985) Cephalic phase of insulin secretion and food stimulation in humans: a new perspective. *Am J Physiol* 249: E639-645. [Crossref]
11. Bellisle F, Louis-Sylvestre J, Demozay F, Blazy D, Le Magnen J (1983) Reflex insulin response associated to food intake in human subjects. *Physiol Behav* 31: 515-521. [Crossref]
12. Teff KL, Levin BE, Engelman K (1993) Oral sensory stimulation in men: effects on insulin, C-peptide, and catecholamines. *Am J Physiol* 265: R1223-1230. [Crossref]
13. Fujise T, Yoshimatsu H, Kurokawa M, Fukagawa K, Nakata M, Sakata T (1993) Food consistency modulates eating volume and speed through brain histamine in rat. *Brain Res Bull* 32: 555-559. [Crossref]
14. Sakata T, Yoshimatsu H, Kurokawa M (1997) Hypothalamic neuronal histamine: implications of its homeostatic control of energy metabolism. *Nutrition* 13: 403- 411. [Crossref]
15. Teff K (2000) Nutritional implications of the cephalic-phase reflexes: endocrine responses. *Appetite* 34: 206-213. [Crossref]
16. Rasmussen H, Zawalich KC, Ganesan S, Calle R, Zawalich WS (1990) Physiology and pathophysiology of insulin secretion. *Diabetes Care* 13: 655-666. [Crossref]
17. Kurose T, Seino Y, Nishi S, Tsuji K, Taminato T, et al. (1990) Mechanism of sympathetic neural regulation of insulin, somatostatin, and glucagon secretion. *Am J Physiol* 258: E220-227. [Crossref]
18. Scrocchi LA, Brown TJ, MaClusky N, Brubaker PL, Auerbach AB, et al. (1996) Glucose intolerance but normal satiety in mice with a null mutation in the glucagon-like peptide 1 receptor gene. *Nat Med* 2: 1254-1258. [Crossref]
19. Miyawaki K, Yamada Y, Yano H, Niwa H, Ban N, et al. (1999) Glucose intolerance caused by a defect in the entero-insular axis: a study in gastric inhibitory polypeptide receptor knockout mice. *Proc Natl Acad Sci U S A* 96: 14843-14847. [Crossref]