Title:

Relationship between mouthful volume and number of chews in young Japanese females

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Highlights:

- The relationship between bite size and the relative number of chews is not clear.
- We examined the relationship between sizes of bites of food and amount of chewing.
- We found that smaller mouthful volumes of food were chewed more.
- Taking smaller bites of food may result in better chewing of food.

Keywords:

mouthful volume, chewing, eating behavior, health promotion

Abstract

Objective: Modification of eating behavior in Japan is promoted to prevent overweight and obesity, but the effects of such modifications are unclear. This study aimed to clarify the inter- and intra-individual relationship between bite size and number of chews of food.

Design and methods: Subjects comprised 50 young healthy Japanese women (mean age 19.5 years). Food materials were boiled rice and apple. First, the average bite size and the number of chews per mouthful of food were calculated across the study cohort. The number of chews was counted by subject's own self and self-reported. Correlation between the individual one-bite volume and the number of chews per volume was analyzed using Spearman's rank correlation coefficient. Second, the number of chews for three different sized bites of food (half of one bite, one bite, and one-and-a-half bites) were calculated as a prospective observational study. The number of chews for each of the three volumes of food was compared using one way ANOVA with Bonferroni correction.

Results: For both food types, there was a negative correlation between individual mouthful volume and number of chews for both food materials. The number of chews per volume decreased as bite sizes increased.

Conclusion: This study demonstrated an inter- and intra-individual relationship between bite size and the number of chews and suggested smaller bite sizes were associated with more chews per volume of food.

Introduction

According to the World Health Organization (WHO), worldwide obesity rates have nearly doubled since 1980. In 2008, it was estimated that, worldwide, 35% of adults aged 20 years and over were overweight and 11% were obese, with the fundamental cause of obesity and overweight being an energy imbalance in an individual's daily diet (WHO, 2013a). In their '10 Facts on Obesity', the WHO also states that overweight and obesity are linked to more deaths worldwide than underweight, and suggest that eating a healthy diet and undertaking regular physical activity can help to prevent obesity (WHO, 2013b). Much research has been undertaken to identify the dietary mechanisms underlying obesity and overweight to identify effective methods for prevention (Hill et al., 1984; Lucas et al., 1984; Westerterp-Plantenga et al., 1990; Kral et al., 2001; Andrade et al., 2008; Viskaal-van Dongen at al., 2011; Leong et al., 2011).

In Japan the Japan Society for the Study of Obesity defines obesity as a body mass index (BMI) ≥25 mg/kg^2 and in the National Health and Nutrition Survey carried out in Japan in 2012, 29.1% of men and 19.4% of women aged 20 years and over were reported to be obese (Ministry of Health, Labour and Welfare, 2013a). The Japanese Ministry of Health, Labour and Welfare mentions that, in addition to excessive energy intake, meal style and eating behavior can also lead to obesity, for example the number, time and regularity of meals, eating quickly or consuming a lot in one meal (Ministry of Health, Labour and Welfare, 2013b).

Among obesity-related eating behaviors, eating quickly has been the subject of previous research (Sasaki et al., 2003; Otsuka et al., 2006; Otsuka et al., 2008; Maruyama et al., 2008). Studies have suggested a relationship between the rate of eating and an individual's current BMI (Sasaki et al., 2003), the change in BMI from 20 years of age (Otsuka et al., 2006), and insulin resistance (Otsuka et al., 2008). It has also been suggested that eating until full and eating quickly are associated with being overweight, and that the combination of both behaviors may have a substantial impact on being overweight (Maruyama et al., 2008).

Regarding eating behaviors such as portion size (Burger et al., 2011), the rate of eating (Martin et al., 2007; Scisco et al., 2011; Ekuni et al., 2012; Higgs et al, 2013), the size of bites (Spiegel et al., 1993; Spiegel, 2000; Zijlstra et al., 2009; Ruijschop et al., 2011; Zijlstra et al., 2011; Forde et al., 2013), and how much food is chewed (Li et al., 2011; Fukuda et al., 2013; Sonoki et al., 2013), it has been suggested that obese individuals take larger sized bites and do not chew their food as much, leading to poor satiety because of short oral exposure, resulting in excessive energy intake (Zijlstra et al., 2009; Ruijschop et al., 2011; Zijlstra et al., 2011). Decreasing the size of bites of food and chewing well have been proposed as ways to increase satiety (Ruijschop et al., 2011; Forde et al., 2013). However the relationship between bite size and the relative number of chews is not yet clear. We formed a hypothesis that small bite size could increase the number of chews not only inter-individually but also intra-individually.

Therefore, the aim of the present study was to clarify the inter- and intra-individual relationship between bite size and the number of chews of food.

Methods and procedures

Study candidates comprised 51 female first to third grade students at the School of Oral Health and Welfare, Faculty of Dentistry, University of Tokushima, Japan. One of the exclusion criteria was any sign and/or symptom of tempolomandibular joint disorders. One participant was excluded for this reason; therefore, the final study cohort comprised 50 healthy, non-overweight females (mean age 19.5 ± standard deviation [SD] 1.1 years, mean BMI 20.2 ± 2.2 kg/m^2).

The following two foods were used as test materials: a bowl of boiled rice, and one-eighth of a piece (approx. 40g) of peeled apple. Packed boiled rice (Sato-no-Gohan®, Sato Foods Co, Ltd. Niigata, Japan) was warmed using a microwave oven as directed and 100 g portions were prepared before the experiments.

This study was conducted with the approval of the Ethics Committee of Tokushima University Hospital (Approval number: 1029). The experimental period was from October in 2010 to April in 2012.

Experiment 1: The inter-individual relationship between an individual mouthful volume and number of chews per volume

Each subject freely took one-bite of boiled rice from a bowl using chopsticks. To calculate the amount of rice taken, the amount of rice remaining in the bowl was weighed using a digital scale. Likewise, each subject took a bite from the piece of apple and the remaining piece was weighed.

After weighing the food, the number of chews for the mouthful of food was counted by subject's own self without any devices and self-reported by each individual. This was repeated three times and the average mouthful volume and number of chews were calculated.

The visual factor like volume may affect to take morsel of food. Therefore we applied the volume of food (cm^3) in this study to remove the effect of differences of food properties like hardness, texture and density. We calculated the volume of food taken by dividing the weight of the morsel of food by its specific gravity (boiled rice 1.12 g/cm^3, apple 0.84 g/cm^3). Correlation between the individual mouthful volume and the numbers of chews per volume was analyzed statistically by Spearman's rank correlation coefficient (<u>$p < 0.05$ was regarded as statistically significant</u>) using IBM® SPSS® Statistics Version 20.0 (IBM Corporation, Armonk, NY, USA).

Experiment 2: The intra-individual relationship between bite size and number of chews per volume

This experiment examined the number of chews for three different sized bites of food as follows: half of one bite; one bite; and one-and-a-half bites. This was done for both the boiled rice and the apple. The half and one-and-a-half bite sizes were based on the weight of the pre-determined average for one bite for each individual. As in experiment 1, the number of chews for each food type and volume were counted three times by subject's own self without any devices and presented as an average.

The number of chews for each of the three volumes of food were compared statistically using one way ANOVA with Bonferroni correction ($p < 0.017$ was regarded as statistically significant).

Results

Experiment 1: The inter-individual relationship between individual mouthful volume and number of chews per volume

Table 1 shows the median mouthful weight and volume, the median number of chews and the median number of chews per weight and volume for each food material. There were significant differences of mouthful weight, number of chews and number of chews per volume, but not volume and number of chews per weight between two food materials.

Figures 1 and 2 show that there was a negative correlation between individual mouthful volume and number of chews for both food materials (boiled rice: $r = -0.597$; apple: $r = -0.648$).

	boiled rice		apple		p value
	median	range	median	range	
weight (g)	9.7	4.0-23.0	6.7	2.0-18.0	p<0.001
volume (cm3)	8.6	3.6-20.5	7.9	2.4-21.4	p=0.820
number of chews (cycle)	35.2	11.3-86.0	27.8	14.3-58.0	p=0.002
number of chew per weight (cycle/g)	3.8	0.7-15.2	4.1	1.4-16.5	p=0.473
number of chew per volume (cycle/cm3)	4.3	0.8-17.0	3.4	1.2-13.9	p=0.011

Mann-Whitney U test

Table 1: The median mouthful weight, volume and the median number of chews across the study cohort (n = 50)

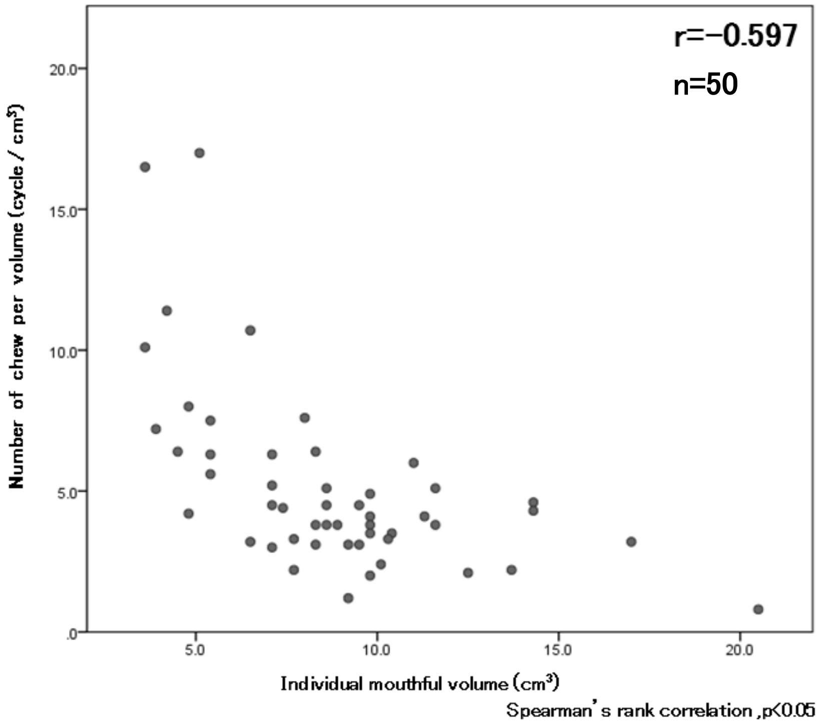

Figure1:Correlation between individual mouthful volume and number of chews per volume of cooked rice

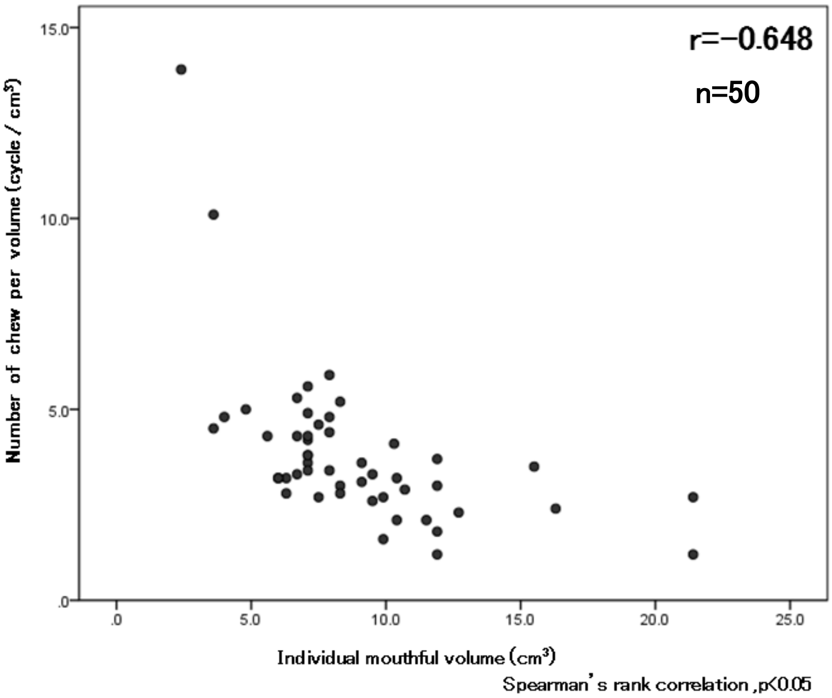

Figure2:Correlation between individual mouthful volume and number of chews per volume of apple

Experiment 2: The intra-individual relationship between bite size and number of chews per volume

The median number of chews for the half, one, and one-and-a-half mouthfuls of boiled rice was 26.5 (± SD 11.6), 35.2 (± SD 15.6), and 45.7 (± SD 19.7), respectively. The number of chews increased with increasing bite size. However when these data were corrected based on the number of chews per volume of food in cm^3, it was found that the numbers of chews decreased with increasing volumes of food (6.1 [± SD 5.0], 4.3 [± SD 3.3], and 3.7 [± SD 2.8] chews/cm^3 for the half, one, and one-and-a-half mouthfuls, respectively, $p < 0.017$) (Figure 3).

Likewise, for apple, the mean number of chews for the half, one and one-and-a-half mouthfuls were 19.3 (± SD 7.4), 27.8 (± SD 9.5), and 39.0 (± SD12.5), respectively. When corrected for the volume of food, a similar pattern to that with boiled rice was observed, with the number of chews decreasing with increasing volumes of food (4.7 [± SD 3.6], 3.4 [± SD

2.0], and 3.1 [± SD 1.7] chews/cm^3, for the half, one, and one-and-a-half mouthfuls, respectively, p <0.017) (Figure 4). Table 2 shows p value of number of chew per weight and volume of the different bite size between boiled rice and apple by Mann-Whitney U test. There were no significant differences of number of chews per weight between two food materials.

Overall, for both apple and boiled rice, the number of chews per volume decreased significantly as the bite size increased.

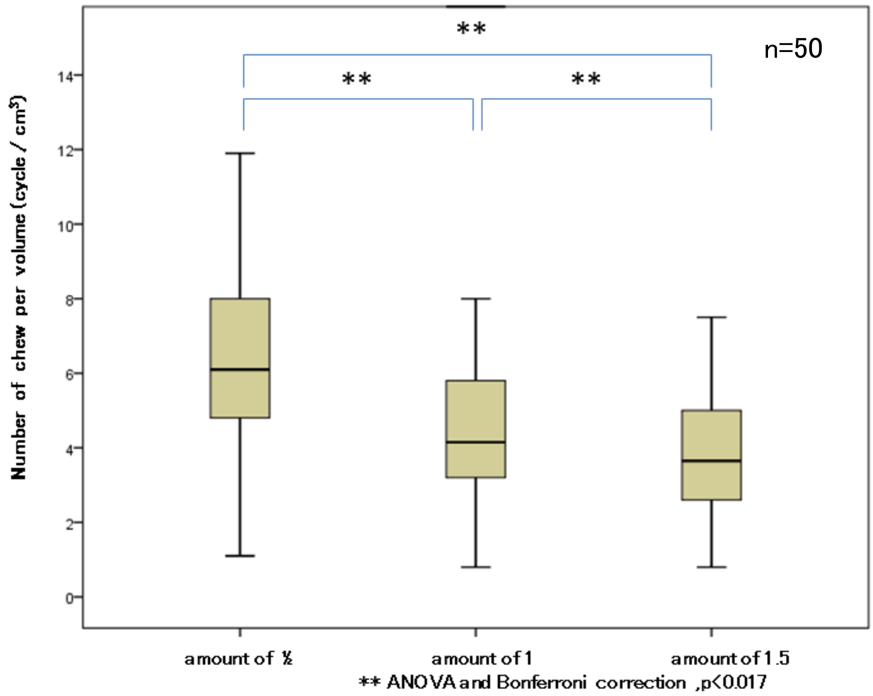

Figure 3:Number of Chews per volume for three different bite sizes of
1 cooked rice

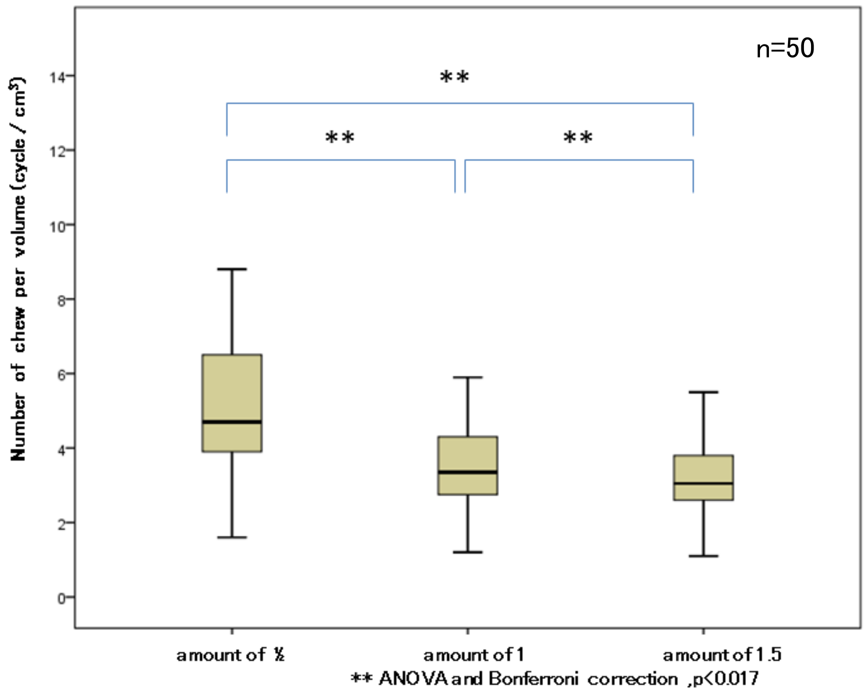

Figure 4:Number of Chews per volume for three different bite sizes of
2 apple

	half of one bite	one bite	one-and-a-half bite
number of chews per weight (cycle/g)	p=0.617	p=0.473	p=0.225
number of chews per volume (cycle/cm^3)	p=0.006	p=0.011	p=0.037

Mann-Whitney U test

Table 2: p value of number of chew per weight and volume of the different bite size between boiled rice and apple (n=50)

Discussion

Obesity and overweight are important global issues, being the fifth leading risk factor for death globally. The WHO states that obesity is largely preventable, and promotes limitation of energy intake, increased consumption of fruits and vegetables, and engagement in regular physical activity in strategies for obesity prevention (WHO, 2013a; WHO, 2013b). The Japanese Ministry of Health, Labour and Welfare focuses on meal style, recommending consuming three regular meals in a day of approximately equal portion size, eating food slowly and chewing effectively, and avoiding eating less than 3 hours before sleeping (Ministry of Health, Labour and Welfare, 2013b). The relationship between obesity and eating behaviors such as chewing well and chewing slowly has also been studied, and consequently the modification of eating behavior is included in health promotion strategies to prevent overweight and obesity in Japan (Ministry of Health, Labour and Welfare, 2013b).

Eating slowly to prevent overweight and obesity is one aspect of eating behavior that has attracted attention in recent decades. Some intervention studies have found that a slow eating rate reduces overall food intake (Martin et al., 2007; Scisco et al., 2011; Ekuni et al., 2012). Regarding eating behavior except eating rate, portion size (Hill et al., 1984; Burger et al., 2011), bite size (Lucas et al., 1984; Spiegel et al., 1993; Spiegel, 2000; Zijlstra et al., 2009; Ruijschop et al., 2011; Zijlstra et al., 2011; Forde et al., 2013) and chewing behaviors (Li et al., 2011; Fukuda et al., 2013; Sonoki et al., 2013) have been studied in various observational studies (Hill et al., 1984; Lucas et al., 1984; Spiegel et al., 1993; Fukuda et al., 2013) and more recently in interventional studies (Sonoki et al., 2013; McGee et al., 2012; Shikany et al., 2011). Contrarily Spiegel has concluded that treatments for obesity should focus on food selection and stimulatory effects of palatability on intake, but not modification of bite size and ingestion rate and other microstructural variables in a review of the topic (Spiegel, 2000).

As these previous studies demonstrate, there is not yet consensus on which eating behavior modifications are effective in preventing overweight and obesity. We agree with the point that achieving behavioral modification of chewing rate is difficult, but we believe that achieving changes in bite size might be easier than changing chewing rate. Generally mouthful size is treated as weight (Westerterp-Plantenga et al., 1990; Zijlstra et al., 2009; Zijlstra et al., 2011; Forde et al., 2013; Scisco et al., 2011; Ekuni et al., 2012). However volume is one of visual factors of food that affected food intake (Wadhera et al., 2014). We focused on a mouthful volume not weight to remove the effect of food properties like hardness, texture and density in the study. Because Table 2 shows no significant differences of number of chew per weight between boiled rice and apple, we could remove the effect of food properties in this study.

In our results, the median mouthful volume of boiled rice was 8.6 cm^3 using chopsticks and that of apple was 7.9 cm^3 taking a bite directly. The mouthful volume of both food materials had no significant difference, but both weights differed. Therefore we focused on the mouthful volume not the weight. And we also demonstrated a strong negative correlation between the individual mouthful volume and chewing number per volume with both food materials between individuals ($r = -0.597$ for boiled rice, $r = -0.648$ for apple). As these foods differ in hardness, texture, and density, this relationship might also be observed with other types of food.

The number of chew are counted by using various methods, e.g. direct observation (Burger et al. 2011; Ekuni et al. 2012; Zhu et al. 2014(2)), via video recorder (Li et al. 2011; Zijlistra et al., 2011; Forde et al., 2013), EMG (Speigel et al., 1993; Frecka et al., 2008), and using any counter device (Scisco et al., 2011; Fukuda et al., 2013). Considering the effect of wearing any devise surrounding the jaw, more naturally eating could be measured under direct observation or on video. The self-count number of chews may make eating more carefully and slowly. However we confirmed no significant deference in number of chew between via video and by subject's self-count for 44 subjects in the preliminary study (boiled rice, p=0.838; apple, p=0.841; Mann-Whitney U test). Therefore we approved subjects' self-count without any devices in this study.

We also examined the intra-individual relationship between chewing number per food volume using different three differently sized bites of food. Our results demonstrated that the smallest volume of food (a half-sized bite) had the greatest number of chews for both boiled rice and apple, and that the number of chews did not increase linearly with increasing food volumes. We suggest, therefore, that modification towards smaller bite sizes leads to increased chewing, and that this might also apply to the effective chewing of other types of foods. Overall, the modification of behavior towards smaller bite sizes might be useful in health promotion strategies to prevent overweight and obesity. There is few intervention study about the relationship between eating behavior and overweight/obesity, Eating behavior has been only suggested to affect factors of overweight/obesity in various retrospective cohort studies (Sasaki et al., 2003; Otsuka et al., 2006; Otsuka et al., 2008; Maruyama et al., 2008; Zhu et al., 2014(1); Zhu et al., 2014(2)). The present study was prospective observational and our results may be limited because the study subjects were lean young Japanese females. To further investigate the effect of modification of bite size, randomized controlled trials including overweight and obese subjects are needed.

In conclusion, this study demonstrated an inter- and intra-individual relationship between bite size and the number of chews. Smaller bite sizes were associated with more chews per volume of food. We suggest that taking small bite sizes is linked to chewing food well, and propose that advocating taking smaller bite sizes could be a useful approach in health promotion strategies for the prevention of overweight and obesity.

Conflicts of interest

None of the authors have any conflicts of interest relevant to the content of this manuscript to declare.

Acknowledgments

Atsuko Nakamichi conceived and carried out the experiments, and analyzed data. Miwa Matsuyama conceived the experiments. Tetsuo Ichikawa analyzed data. All authors were involved in writing the paper and approve the submitted and published versions.

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Table and figure legends

Table 1: The median mouthful weight, volume and the median number of chews across the study cohort (n = 50)

SD = standard deviation, Mann-Whitney U test

Table 2: P value of number of chew per weight and volume of the different bite size between boiled rice and apple (n=50)

Mann-Whitney U test

Figure1: Correlation between individual mouthful volume and number of chews per volume of boiled rice (n = 50)

Figure 2: Correlation between individual mouthful volume and number of chews per volume of apple (n = 50)

Figure 3: Number of chews per volume for three different bite sizes of boiled rice (n = 50)

Figure 4: Number of chews per volume for three different bite sizes of apple (n = 50)