PEDIATRIC DENTAL JOURNAL 20(1): 22–27, 2010

Cross-sectional analysis of age-related changes in the fluctuation of bite size

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Abstract It has been reported that individual adults generally take consistently sized bites when eating the same food, while children do not. The present cross-sectional analysis was performed on 60 children and 20 adults to ascertain the age-related changes in the fluctuation in bite size and in the number of chews per bite. The subjects comprised four age groups (5-, 8-, and 11-year-old children and adults), with each group consisting of 10 males and 10 females. The subjects were instructed to take a bite of each of four test foods (bread, sausage, apple and rice), and they were allowed to chew and swallow as usual. After each bite, the remaining food was weighed to calculate the bite size. The fluctuations in bite size and in the number of chews were analyzed using coefficients of variation. The fluctuations in both bite size and the number of chews decreased with age, so that the 11-year-olds showed almost the same values as adults. The present results suggested that the physiological functions related to recognizing and consuming foods mature during early adolescence, when almost all permanent teeth have erupted. The present findings also indicated that the fluctuation in bite size might be an indicator of the maturation of masticatory function in children.

Key words
Bite size,
Chews,
Children,
Feeding behavior,
Growth

Introduction

During mastication, the intake of food into the mouth is equivalent to the anticipatory and preparatory stages of ingestion[1]. At this stage, humans use their visual and olfactory senses to decide what and how much to eat and to ascertain bite size before taking a bite. It has also been stated that individual memory based on past dietary experience is an important factor in bite size[2].

Previous studies have shown that adults take consistently sized bites when eating the same food[3–5]. However, Yagi *et al.*[6] reported that children take bites of different sizes and that these fluctuations decrease with age. Furthermore, it has been reported that children widely vary the number of chews they take before swallowing.[7] To the best of our knowledge, no studies have analyzed age-related changes in fluctuations in both bite size and the number of chews per bite together.

The purpose of the present cross-sectional study was to clarify age-related changes in the fluctuations in bite size and the number of chews in children at the same time, and to ascertain when children acquire the physiological ability to take consistently sized bites.

Received on September 24, 2009
Accepted on January 20, 2010

Subjects and Methods

Subjects

Eighty subjects were divided into the following four age groups, each consisting of 10 males and 10 females: a 5-year-old group (average age: 5 years and 6 months, Hellman dental age IIA or IIC), an 8-year-old group (average age: 8 years and 8 months, Hellman dental age IIIA or IIIB), an 11-year-old group (average age: 11 years and 10 months, Hellman

Table 1 Subjects in the present study

Group	Number (male/female)	Age (average)	Hellman dental age
5-year-old	20 (10/10)	5y 0m– 5y10m (5y 6m)	IIA, IIC
8-year-old	20 (10/10)	8y 0m– 9y 5m (8y 8m)	IIIA, IIIB
11-year-old	20 (10/10)	11y 3m–12y 9m (11y10m)	IIIB, IIIC
Adults	20 (10/10)	24y 8m–29y 0m (26y 8m)	IVA

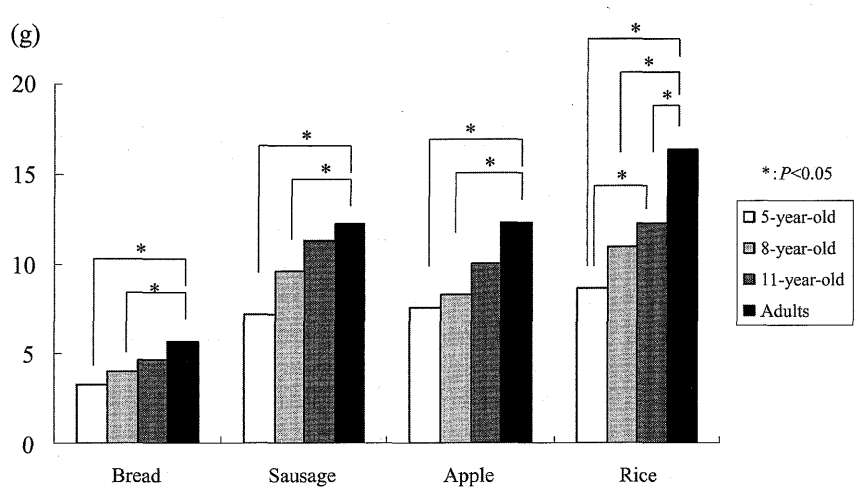

Fig. 1 The average bite size of each test food for each age group

dental age IIIB or IIIC), and an adult group (average age: 26 years and 8 months, Hellman dental age IVA) (Table 1). All of the subjects had normal occlusion and no stomatognathic abnormality. The adult subjects did not have any missing teeth. Informed consent was obtained from each child and his or her legal guardian, and from each adult subject.

Test foods

The test foods were bread (40 g butter roll, Masuya Bakery, Niigata, Japan), fish sausage (90 g, Marudai Food, Osaka, Japan), peeled apple (60 g Jona Gold, Japan), and ready-prepared rice (100 g, Sato Foods, Niigata, Japan). Each food was prepared in the same shape. Before the experiment, we confirmed that all subjects were able to eat the four test foods.

Eating experiment

On the same day, each subject was asked to eat two test foods, with a break of 5 minutes between each food. The test was undertaken between 3 and 6 pm. Rice was eaten using chopsticks, and the other foods were eaten using the fingers. The subjects were instructed to take a bite and then to chew and swallow as usual. After we confirmed there was no food left in their mouths, we asked them to take another bite.

After each bite except the last one, the remaining food was weighed to calculate the bite size. Each food was tested until the subject had taken at least six bites. The experimental run of all events was recorded on videotape to count the number of chews per bite.

Statistical analysis

The fluctuations single bite size and in the number of chews were analyzed using coefficients of variation (Excel Statistics Version 5.0, Esumi, Tokyo, Japan). The Tukey-Kramer test was used to compare the different age groups, and the Steel-Dwass test was used for the median coefficients of variation among the age groups. Statistically significant differences were set at the level of $P<0.05$.

Results

1) Average bite size

Figure 1 show the average bite size of each test food

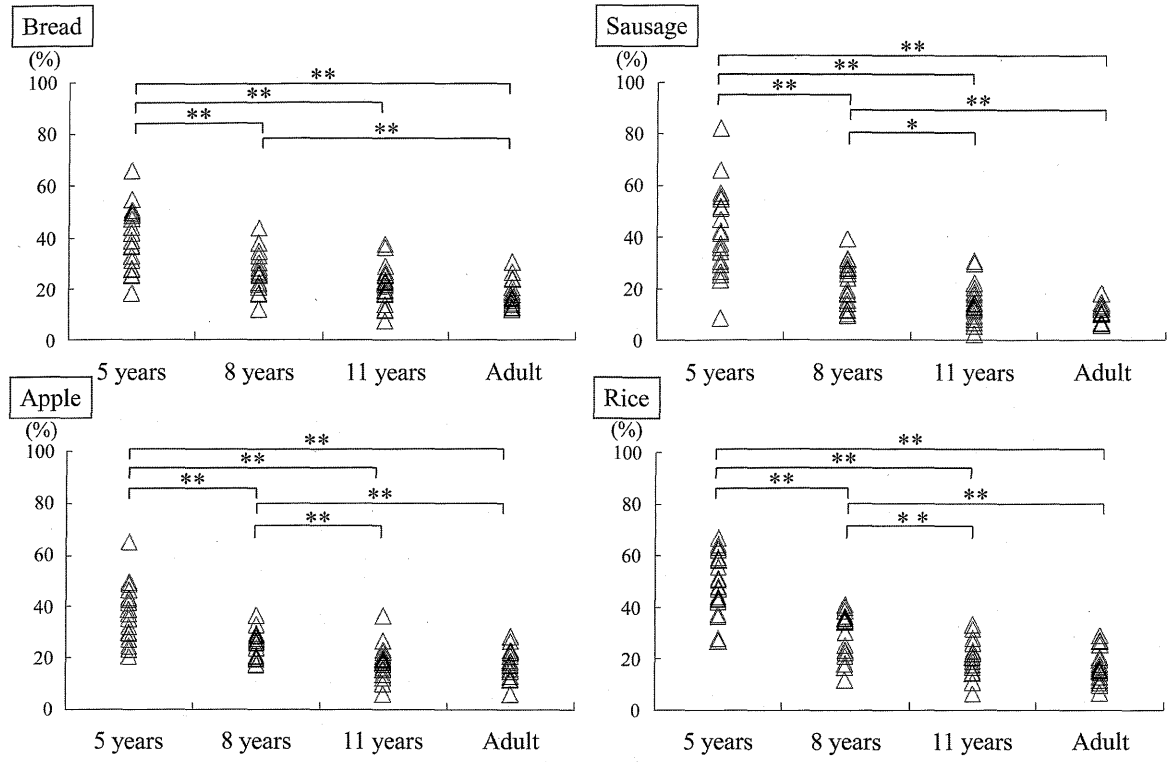

Fig. 2 The fluctuations in single-bite size of each test food
Each plot in the figure represents the coefficient of variation for each subject. *: $P<0.05$, **: $P<0.01$

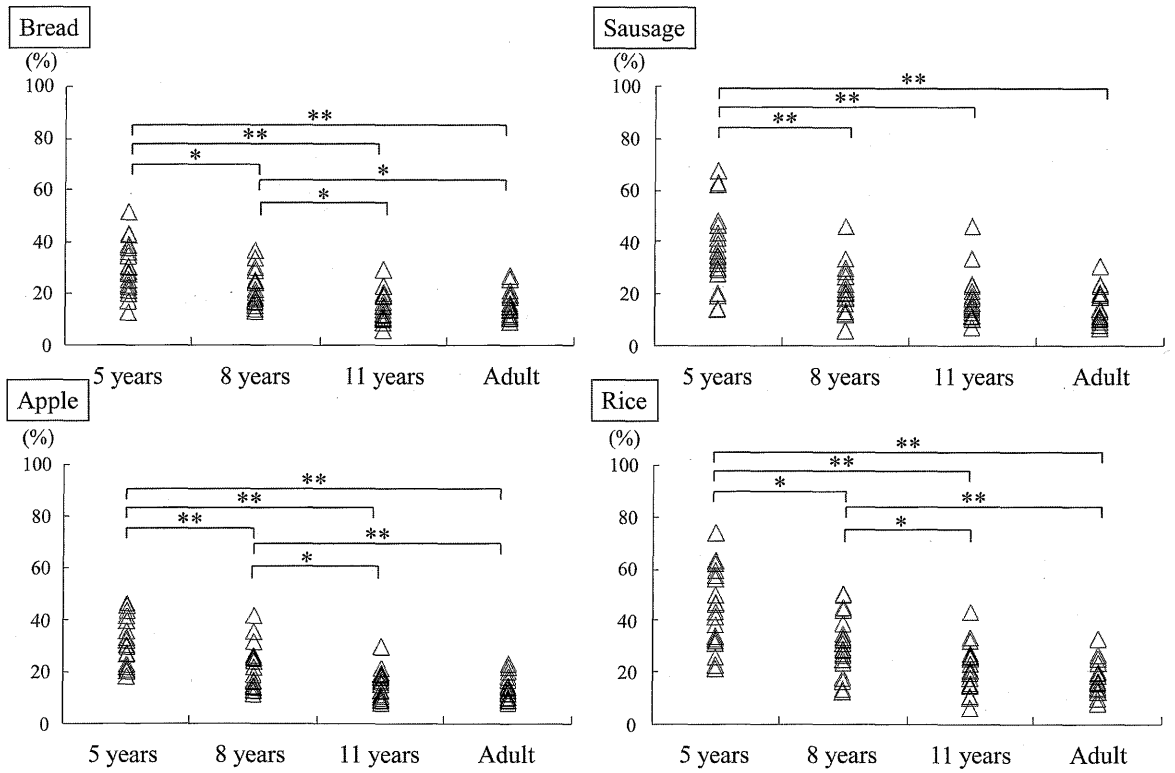

Fig. 3 The fluctuations in the number of chewing strokes per bite
Each plot in the figure represents the coefficient of variation for each subject. *: $P<0.05$, **: $P<0.01$

in each age group. In all test foods, bite size tended to increase with age from 5 years to adulthood, and adults took significantly larger bites than 5-year-olds and 8-year-olds. However, for all foods except rice, the average bite size did not differ significantly between the 11-year-old children and the adults.

2) Fluctuations in bite size

The fluctuations in bite size for each subject were analyzed using coefficients of variation (Fig. 2). In all test foods, the coefficient of variation in the 5-year-old group was significantly greater than in the other three age groups. The coefficient of variation in the 8-year-old group was significantly greater than in the 11-year-old group and the adult group, except in the case of bread. In all test foods, no significant difference was apparent in the fluctuations in bite size between the 11-year-old group and the adult group.

3) Fluctuations in the number of chews per bite

Figure 3 shows the fluctuations in the number of chews per bite using coefficients of variation. In all test foods, the coefficient of variation of the number of chews per bite in the 5-year-old group was significantly greater than those in the other three age groups. The coefficient of variation in the 8-year-old group was greater than those in the 11-year-old and adult groups for all foods except sausage. For all test foods, no significant difference was found in the fluctuations in the number of chews per bite between the 11-year-old group and the adult group.

Discussion

1) Age-related changes in average bite size

The results of the present study clarified that the average bite size increased with age for all test foods, and that bite size in the 11-year-old group was similar to that in the adult group for all test foods except rice.

Growth changes in oral cavity volume are considered a factor in the increment in bite size. Watanabe *et al.*[8] reported that the surface area of the oral cavity in 5-year-old children was 54.8% of that in adults. It has also been reported that the inter-canine, inter-premolar, and inter-molar widths of the upper dental arch gradually increased from the ages of 5 to 13 years[9], and that the upper and lower inter-canine widths increased until the age of 11 years, when permanent canines become involved in functional occlusion[10]. Therefore, oral cavity volume is thought to increase with age until all permanent teeth erupt except for the third molars. The present finding that the average bite size of children reached that of adults at around the age of 11 years may suggest that bite size increases as oral cavity volume increases.

Based on six-degrees-of-freedom analysis, Kikuchi[11] reported that the range of vertical mandibular incisor movements was largest in permanent dentition, followed by mixed dentition and deciduous dentition. Since the function of food intake into the mouth is related to the masticatory movements using the incisors[12], the age-related increase in the range of incisor movements may be a factor in the age-related increases in bite size. Among the test foods, only rice showed a significant difference in bite size between the adult group and the other three age groups. In the present study, rice was eaten with chopsticks, while the other test foods were eaten with the fingers. This difference in bite size changes may be related to the development of the ability to use chopsticks, which is attained later than the ability to eat with the fingers. Further investigation should be needed to clarify the age-related changes in bite size of rice eaten with the fingers.

2) Fluctuations in bite size

Previous studies have reported that bite size of the same food was consistent in adults but not in children[3–6]. The results of the present study clarified that the fluctuations in bite size decreased with age until the age of 11 years, when fluctuations were nearly the same as those among adults.

Bite size is determined by food recognition and food intake into the mouth. This involves neural regulation and requires complex functions such as food recognition and hand-mouth coordination[5]. In general, this aspect of the central nervous system begins to develop after birth. It is about 80% complete among 5-year-olds, 95% among 8-year-olds, and essentially 100% complete around the age of 11[13]. As the central nervous system as well as the function of food recognition and intake develops with age, the fluctuations in bite size are considered to decrease with age.

Previous studies have shown that bite size is related to experience and memory[1,2]. Leopold *et al.*[1] and Yamada *et al.*[2] stated that during a recognition period prior to food intake, the size of food intake was determined using the visual and olfactory senses based on experience. Mojet *et al.*[14] also reported that the memory of foods played an important role in human ingestion. Experience with specific foods

might be related to the present developmental change in the fluctuations in bite size.

Since the subjects in the 8-year-old and the 11-year-old groups were in a mixed dentition and some primary anterior or posterior teeth exfoliated or exhibited mobility, a question arises whether the discontinuous or unstable dentition affected on the present results or not. A hypothesis can be built up that the fluctuations in bite size would be increased because the chewing function might decrease due to the above condition. In the present study, however, the fluctuations in bite size decreased with age. This result strongly suggests that the function of food intake into the mouth is influenced more markedly by the development of the central neural regulation such as food recognition, experience and memory than the peripheral and local factors such as the condition of dentition.

3) Fluctuations in the number of chews per bite

The present results showed that the fluctuations in the number of chews decreased with age and seemed to stabilize at adult levels around the age of 11 years. Interaction between the volume of food intake and the number of chews has been reported[15–17]. It was considered, therefore, that according to the decrease in the fluctuations in bite size with age, the fluctuations in the number of chews per bite also decreased.

The number of chews is influenced not only by the physical properties of food, such as solidity, cohesiveness, viscosity, elasticity, and moisture content, but by the swallow threshold of each individual[18]. In the present study, in all four test foods with different properties, the fluctuations in the number of chews per bite diminished with age in the same pattern. This suggests that the large fluctuation in the number of chews per bite during childhood does not depend on the food properties and swallow threshold of each individual but on the immature recognition of food intake.

4) Bite size as an indicator of masticatory function development

Since the quantity of a mouthful of food differs from person to person, it was quite difficult to assess the developmental changes in children by bite size only. The results of the present study clarified that the fluctuations in bite size decreased with age. Moreover, the fluctuation stabilized around the age of 11 years, when almost all permanent teeth have erupted. The method we used to analyze fluctuation standardized the differences among the individuals. As mentioned above, the decrement in fluctuations in bite size is considered related to the maturation of the central nervous system involving complex functions of food recognition and hand-mouth coordination. The present study, by assessing the fluctuations in bite size using coefficients of variation, revealed that the fluctuations diminished with age, suggesting that fluctuation may be used to evaluate the maturation of the masticatory function in children.

Conclusions

The present study demonstrated that average bite size gradually increased with age and reached adult levels around the age of 11 years, and that the fluctuations in both bite size and the number of chews per bite decreased with age, reaching adult levels around the same age.

The findings of the present study suggested that the physiological functions concerned with food recognition and intake during eating and swallowing develop with age to reach adults level during early adolescence, when the permanent teeth have fully erupted. It was proposed that the fluctuations in bite size could be used to assess the maturation of masticatory function in children.

Acknowledgments

This research was supported by a Grant from the Futoku Foundation in 2009 for research projects.

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