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Comparison of the effects of chewing foods on saliva flow rate in children and adults

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Abstract

Objectives: The purpose of this study was to evaluate the effects of different foods and citric acid concentrations on the flow rate of saliva in children and adult subjects.

Methods: The subjects were 20 young adults and 20 five-year-old children who were all in good health and with normal dentition. The selected foods were steamed rice, cookies, and apples. The volume of saliva was determined by subtracting the initial weight of the food from that of the food bolus after the subjects had chewed normally. The flow rates were compared with those produced in response to infusion into the mouth of 52 and 156 mmol/l citric acid.

Results: The mean flow rates with foods and citric acid were significantly slower in the children than in the adults, and the mean chewing time per 10 g of food was significantly longer in the children than in the adults. The mean water content of the food bolus after chewing was not significantly different between the two groups.

Conclusions: Saliva secreted by foods is secreted to get a fluid volume of the food bowl necessary to swallow for both a child and adult, and the water content of the food bolus appears to be a factor in the decision to swallow.

Introduction

The presence of food in the mouth is a powerful stimulus for salivation, and it is generally accepted that the main components of this effect are gustatory stimulation and masticatory movements. There have been many studies on the flow rate of saliva secreted in response to acidic gustatory stimulation [1] or to mechanical stimulation from chewing inert materials such as paraffin wax [2] however, there have been few studies of the secretory response to foods. Richardson and Feldman [3] reported a mean salivary flow rate of 2.72 ± 0.22 ml/min in 34 subjects in response to a meal of steak, french-fried potatoes, and water. Watanabe and Dawes [4] evaluated the effects of chewing seven commonly consumed foods on the flow rate of whole saliva in 32 subjects.

Most studies on salivary secretion in humans have been carried out using adult subjects, and there is little information about salivary secretion in children. The purpose of this study was to evaluate the effects of different foods and concentrations of citric acid on the flow rates of saliva in five-year-old children and compare these with the saliva flow rates in adult subjects.

Materials and methods

The present study was approved by the Ethics Committee of Meikai University.

Subjects

The subjects were 20 young adults (10 females and 10 males, 21–32 years of age) and 20 five-year-old children (10 boys and 10 girls) who were all in good health and with normal dentition. The parents of the child subjects consented to their participation in the study.

Experimental procedure

The flow rate of unstimulated whole saliva was determined at about 2:00 p.m., at least one hour after a meal. The subjects were seated, with their heads down, and saliva was collected for 5 min by allowing it to drip off the lower lip into a weighed container. The subjects swallowed immediately before the collection. At the end of the collection, they forcibly spat out into the container any saliva remaining in their mouths, and the saliva was weighed [5]. The children were closely observed during the 5-min collection period to ensure that they did not swallow.

After the unstimulated salivary flow rates had been determined, the subjects' teeth were coated with Vaseline to protect them from any deleterious effects from the acid. Citric acid (52 mmol/l; 1%) was infused into the subjects' mouths for 70 s through a plastic tube, at a rate of exactly 5.0 ml/min using a peristaltic pump (MP-3, EYELA; Rikakikai Co., Tokyo, Japan). The subjects were encouraged to constantly move the acid around their mouths. After the first 10 s, during which the maximum salivary flow rate was reached [6], the subjects spat out the

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acid and any saliva at approximately 10-s intervals. The acid and saliva were collected into a weighed container. The volume accumulated over 1 min, minus the 5.0 ml of infused acid, was the stimulated saliva flow rate. After a rest period of several minutes, this procedure was repeated using 156 mmol/l (3%) citric acid.

The tested foods were steamed rice, cookies, and apples. The foods were weighed to the nearest 10 mg on a top-loading balance (1202MP; Sartorius, Germany). The subjects chewed their usual bite-size portions until such time as they would normally have swallowed; then they spat out the food bolus into a weighed container. The time required for all of the food to be masticated and spat out was recorded. The volume of saliva secreted in that time was determined by subtracting the initial weight of the food from that of the food–saliva mixture.

Calculation of food swallowed or retained

Calculations were performed by the method of Watanabe and Dawes [4]. For six of the subjects, the dry weights of the rice– and apple–saliva mixtures (fat-free foods) were obtained after heating. The dry weights of the same unchewed batches of rice and apple were also determined, which enabled us to calculate the percentage of the food that was either inadvertently swallowed or retained in the mouth and not expectorated. If: a = initial weight of food, b = weight of food + saliva, c = dry weight of food/saliva mixture, d = % dry wt, e = % dry wt of saliva alone (0.5% [7]), f = % of food swallowed or retained in the mouth; then:

$$f = 1 - \frac{c - e\frac{(b-a)}{100}}{\frac{ad}{100}} \times 100(percent)$$

Statistics

A mixed analysis of variance was used to determine the effects of gender, citric acid concentration, and food type on the stimulated salivary flow rate, expressed both as ml/min and as a percentage of the maximum flow rate attained with the acid. When the F value was significant, Duncan's new multiple range test was used to determine significant individual differences.

Results

Since there were no significant effects of gender on any of the measurements, the results for males and females were pooled.

Table 1 shows the mean flow rates of unstimulated whole saliva and the flow rates elicited in response to the two concentrations of citric acid in child and adult subjects. The flow rates are expressed as ml/min and as percentages of the flow rates in response to 156 mmol/l citric acid. There were significant differences between the flow rates in response to 52 mmol/l citric acid and 156 mmol/l citric acid ($p < 0.005$).

Table 2 shows the mean weights of the foods and comparisons of the mean chewing times for 10 g of each food in children and adults. There were significant differences in chewing times between the children and the adults with each food ($p < 0.05$).

Table 3 shows the initial water content of each food and comparisons of the mean water content of each food after chewing by the children and adults. The water content of the foods after chewing was determined from the initial water content of the food and the volume of saliva secreted during chewing. There were no significant differences between the children and adults in the water content after chewing any of the foods.

Table 4 compares the mean salivary flow rates in response to each food in the children and adults. The children had significantly lower flow rates than the adults with each food ($p < 0.05$).

The percentage of food that was either inadvertently swallowed or remained on the teeth or oral mucosa was calculated to be 8.2% ± 3.4% (children) and 5.9% ± 3.8% (adults) for rice and 7.2% ± 3.0% (children) and 5.8% ± 2.9% (adults) for apple. These values were not significantly different. The computed flow rates in Table 4 were not adjusted and were presumed to be slight underestimates.

Discussion

Although the unstimulated salivary flow rate in adults is relatively unaffected by various psychological stimuli, such as slight mental stress [8], some younger children are easily disturbed by dental visits. In the present study, all of the child subjects were patients receiving regular checkups and had previously received dental treatments or preventive care at the Department of Pedodontics. The subjects in these experiments readily volunteered to take part and did not appear to be nervous during the procedures.

The flow rate of unstimulated whole saliva has been studied by several investigators, including Heintze et al. [9] in 286 males (0.36 ml/min) and 343 females (0.26 ml/min). However, little information is available about salivary flow rates in children. In the present study, there was no significant effect of gender on the unstimulated salivary flow rates in children, and the mean value was lower than that in the adults. Presumably, the salivary glands of younger children have not reached their maximum development and secretory capacity.

Table 1. Unstimulated salivary flow rate and flow rates elicited in response to citric acid.

Stimulus	Children (n=20)		Adults (n=20)	
	Flow rate as ml/min (mean ± S.D.)	Flow rate as a percentage of that evoked by 156mmol citric acid (mean ± S.D.)	Flow rate as ml/min (mean ± S.D.)	Flow rate as a percentage of that evoked by 156mmol citric acid (mean ± S.D.)
Unstimulated	0.26 ± 0.14	6.5 ± 3.6	0.40 ± 0.25	9.2 ± 3.1
52mmol/l citric acid	2.43 ± 1.16	72.0 ± 16.2	4.31 ± 1.90	74.3 ± 13.8
156mmol/l citric acid	3.38 ± 1.22	100	5.80 ± 2.22	100

* $p < 0.005$

S.D. = standard deviation

Table 2. Mean weights of foods and comparison of the mean chewing time for 10g of food between children and adults.

Food	Food wt.(g)	Children	Adults
Rice	50.1 ± 6.5	40.1 ± 17.1	30.1 ± 10.1
Cookie	50.3 ± 7.5	59.5 ± 18.4	50.3 ± 14.8
Apple	80.2 ± 12.5	35.9 ± 14.2	24.4 ± 8.9

* $p < 0.05$

Table 3. Initial water content of food and comparison of the mean water content of food after chewing between children and adults.

(%)

Food	water content of food	children	Adults
Rice	59.8 ± 1.4	62.0 ± 3.5	63.8 ± 3.1
Cookie	3.0 ± 0.3	31.8 ± 3.8	30.4 ± 5.5
Apple	8.2 ± 1.2	86.4 ± 2.3	87.1 ± 1.2

Table 4. Comparison of the mean salivary flow rates in response to each food between children and adults.

(ml/min)

Food	children	Adults
Rice	2.54 ± 1.11	3.31 ± 1.51
Cookie	3.03 ± 1.01	4.89 ± 1.50
Apple	3.54 ± 1.65	4.31 ± 1.61

* $p<0.05$

In humans, the volume of saliva induced reflexively by taste stimulation varies markedly depending on the nature of the stimulus. Of the four basic taste stimuli (sour, salty, sweet, and bitter), acid (sour) is by far the most potent even when the subjective intensities of the four stimuli are equal [10].

In all 40 subjects, 156 mmol/l citric acid elicited the highest flow rate. Since Vaseline was applied to the teeth, the effect of the acid on the teeth was not observed. A significant difference was found between the children and adults in saliva secretion rate with the citric acid solution. However, there was no difference between the children and adults in the change in secretion rate between 52 mmol/l and 156 mmol/l citric acid. The mean saliva flow rates for the children with the apple, rice, and cookie were approximately 82.1%, 76.7%, and 62.0%, respectively, of the adult rates. Although there is a difference in the salivary secretion capacity between children and adults, the secretary response to taste stimuli intensity appears to be similar.

There is considerable uncertainty about the properties of a food bolus that triggers swallowing. Our results show that the mean water content of the different food boluses varies over a wide range. Therefore, the water content of the bolus cannot be the primary factor in the decision to swallow; presumably, some textural property of the bolus is more important. However, our findings do show a significant negative correlation between the initial water content of a food and the chewing time per 10 g of food.

Conclusions

Saliva secreted by foods is secreted to get a fluid volume of the food bowl necessary to swallow for both a child and adult, and the water content of the food bolus appears to be a factor in the decision to swallow.

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