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ORIGINAL ARTICLE

M Kibayashi

The relationships among child's ability of mastication, dietary behaviour and physical fitness

Author's affiliation:
Miyuki Kibayashi, Department of Dental Hygiene, Junior College, University of Shizuoka, Shizuoka, Japan

Correspondence to:
Miyuki Kibayashi
Department of Dental Hygiene
Junior College
University of Shizuoka
2-2-1 Oshika
Suruga-ku
Shizuoka-city 422-8021
Japan
Tel./Fax: +81 54 202 2672
E-mail: kibamiyu@u-shizuoka-ken.ac.jp

Abstract: To investigate the relationships between the ability of mastication and physical fitness, and between the ability of mastication and dietary behaviour in children, I examined these parameters using the data of sugar elution rate, physical fitness and athletic ability survey and self-administered questionnaire on dietary behaviour on 171 sixth grade children (88 boys and 83 girls). The sugar elution rate was the index of the ability of mastication and was evaluated by the chewing gum method. The results of self-administered questionnaire on dietary behaviour were used as an index of dietary behaviour. Physical fitness was evaluated by the physical fitness and athletic ability survey of the Ministry of Education, Culture, Sports, Science and Technology, Japan. Regression analysis revealed that the sugar elution rate had significantly positive correlations with the mean grip strength, sit-up, sit-and-reach, repetition side steps and ball throw. The results of self-administered questionnaire on dietary behaviour revealed that the sugar elution rate was significantly higher in children, who had high expectation of food intake and high frequency of vegetable intake, than those with lower parameters. These results suggest that the ability of mastication correlates with physical fitness and dietary behaviour in children.

Key words: athletic ability survey; dietary environment; elementary school children; physical fitness; sugar elution rate

Introduction

Recently, the children's physical strength has shown a tendency to decrease in the long run (1). The Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT) proposes that physical strength is one of the most important factors to develop the human's growth and promotes three healthy principles (balanced diet, appropriate exercise and enough rest and sleep) for the children to overcome this decreasing tendency of physical strength.

A previous study revealed the relationships among bite condition, health outlook and physical fitness (2). However, these factors did not examine the relationship with the ability of mastication. To support balanced nutrient intake and healthy dietary behaviour in children, it is important to maintain an excellent environment in the mouth. Therefore, it is necessary to develop the ability of mastication to eat food delectably and to chew food well.

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Objective

This study aimed to clarify the relationship of the ability of mastication with dietary behaviour and physical fitness in the late childhood.

Study population and methodology

Subjects

Of the sixth grade pupils in the elementary schools in Japan, 171 children (88 boys and 83 girls) participated in the test of the ability of mastication and self-administered questionnaire on dietary behaviour. The degree of obesity (3, 4) was 1.46 ± 16.0 in all children (n = 171), 3.39 ± 16.1 in boys (n = 88) and −0.59 ± 15.7 in girls (n = 83). In addition, 55 (26 boys and 29 girls) of the 171 children also participated in the physical fitness and athletic ability survey of MEXT. This study was approved by the ethical committee of the Department of Dental Hygiene, Shizuoka Junior College, University of Shizuoka (No. 20-10) and was executed as a part of the health work after obtaining an original consent of the school principal of the target school and year. Moreover, all participants and their parents were told about the purpose of this study with oral and written explanation, and they provided informed consent.

Self-administered questionnaire on dietary behaviour and lifestyle

To investigate the dietary behaviour in the daily life, self-administered questionnaire was used. This questionnaire consisted of 29 questions, including the daily greeting behaviour, the degree of interest in diet, the feeding situation in breakfast, the mastication consciousness, health consciousness and feeling of fun in the school (5). Regarding the answers, the subjects had to select one of the four choices: 'Apply', 'Somewhat apply', 'Apply a little' and 'Do not apply'.

Measurement of ability of mastication

Chewing gum method

To directly assess the ability of mastication in the eating behaviour, the chewing gum method (6) was used. The participants chewed gum (1.7 g/peace, including 1.66 ± 0.04 g of xylitol) (LOTTE, Tokyo, Japan) freely for 40 sec, and the eluting amount of sugar (sugar elution rate) was calculated (7).

Measurement of pressure-sensitive films method

The occlusal force was assessed by the pressure-sensitive films (DENTAL PRESCALE 50 H type R, GC Corporation, Tokyo, Japan) and the occlusal force measuring system (Occluzer FPD-703, GC Corporation), and I evaluated the occlusal area (Area), average occlusal pressure (Ave), maximum occlusal pressure (Max) and occlusal force (Force). During measurement, the participants were asked to bite the pressure-sensitive film maximally at the intercuspation title. The participants performed this procedure several times, and the data were collected.

Measurement of physical fitness

The physical fitness and athletic ability survey of MEXT (grip strength, sit-up, sit-and-reach, repetition side steps, 20-m shuttle run, 50-m run, standing jump and ball throw) were used to evaluate the level of physical fitness (8). The record of the test was made a point from the scorebook of the test of each man and woman who had been put out from MEXT according to the item. The results of each test were scored by 1–10 points according to the scorebook of physical fitness and athletic ability survey (9).

Statistics

The relationship among the ability of mastication and the results of physical fitness and athletic ability survey was analysed by Pearson's product-moment correlation coefficient. The unpaired t-test was used to assess the sex differences in the ability of mastication and the differences in the sugar elution rate between groups, which were divided according to the results of self-administered questionnaire on dietary behaviour. Values of $P < 0.05$ were considered significant. The data are presented as the mean ± SD, and analyses were conducted using SPSS Ver. 14 (SPSS Inc., Chicago, IL, USA).

Results

Table 1 shows the ability of mastication. In all parameters, there were no sex differences.

Table 1. **The ability of mastication and obesity index**

Items	All (n = 171) (mean ± SD)	Boys (n = 88) (mean ± SD)	Girls (n = 83) (mean ± SD)	Sex difference
Sugar elution rate (%)	61.7 ± 6.20	62.0 ± 6.48	61.5 ± 5.91	NS
Area (mm^2)	6.29 ± 3.60	6.40 ± 3.69	6.17 ± 3.53	NS
Max (Mpa)	108 ± 12.4	107 ± 13.1	110 ± 11.5	NS
Ave (Mpa)	47.0 ± 7.60	46.0 ± 7.76	47.9 ± 7.39	NS
Force (N)	291 ± 157	288 ± 156	294 ± 160	NS
Obesity index (%)(HIBI style)	1.46 ± 16.0	3.39 ± 16.1	−0.59 ± 15.7	NS

NS, not significant; t-test.

The results of dietary behaviour were divided into two groups in terms of the quality. There were significant differences in the sugar elution rate between the group of 'I'm looking forward to eating food' and the others, between the group of 'I eat vegetables more than twice a day (without lunch)' and the group of 'I eat vegetables less than once a day', and between the group of non-obese (<20% in the degree of obesity) and the group of obese (≥20% in the degree of obesity) (Table 2).

Table 3 shows the results of physical fitness and athletic ability survey and the ability of mastication in 55 children. There were no sex differences in the ability of mastication.

Regression analysis revealed that the sugar elution rate had significantly positive correlations with the mean grip strength, sit-up, sit-and-reach, repetition side steps and ball throw (Table 4). To clarify the relationship between the ability of mastication and physical fitness, the score of five measurement items of physical fitness and athletic ability survey, which had significant correlations with the ability of mastication, were summed, and I classified the results into two groups [≧mean + 1 SD (n = 11) and ≦mean − 1 SD (n = 10)]. As a result, the sugar elution rate in the group of '≧mean + 1 SD' was significantly higher than that in the group of '≦mean − 1 SD' (Table 5).

Discussion

Recently, it was reported that the problems of dietary behaviour influenced the physical, mental and social aspects of children (10). Murai *et al.* (11) reported that the children's expectation to the meals was influenced by selection behaviour of meal and action of cooking of the parents at home. In humans, it is considered that the mentality, personality, five senses and sense of unity are developed or formed by eating food with family or group, and this advances pleasantness and sense of expectancy about meals (12). Furthermore, Kawasaki (13) reported that having comfortable atmosphere during eating food affects the mental health in children. This study demonstrated that there was a relationship between the sugar elution rate and the feeling of expectation for meals, suggesting that the ability of mastication correlates with the dietary behaviour. This is because some investigators considered that the experience of spending pleasant atmosphere with family while eating food is memorized with taste, and this affects dietary behaviour. Therefore, it is necessary to maintain a good dietary environment that would improve the children's expectations of meals.

The sugar elution rate in the group of 'I eat vegetables more than twice a day (without lunch)' was significantly higher than

Table 2. **Differences of dietary behaviour and obesity index based on ability of mastication**

	Expectations to meal*		Intake frequency of vegetable**		Obesity index (HIBI style)*	
	Meal is fun (n = 77) (mean ± SD)	Others (n = 94) (mean ± SD)	2 times or more/day (n = 143) (mean ± SD)	1 time or less/day (n = 28) (mean ± SD)	Non-obesity (Less than 20%) (n = 149) (mean ± SD)	Obesity (20% or more) (n = 22) (mean ± SD)
Sugar elution rate *(%)*	62.9 ± 6.7	60.8 ± 5.6	62.3 ± 6.2	59.0 ± 5.7	62.1 ± 6.1	59.0 ± 6.5

t-test; *P < 0.05; **P < 0.01.

Table 3. **The physical fitness and ability of mastication**

Physical Fitness and Athletic Ability Survey items	All (n = 55) (mean ± SD)	Boys (n = 26) (mean ± SD)	Girls (n = 29) (mean ± SD)	
Mean grip strength (points)	6.85 ± 1.81	7.10 ± 1.58	6.63 ± 1.99	
Sit-up (points)	7.59 ± 2.01	8.07 ± 1.69	7.18 ± 2.20	
Sit-and-reach (points)	6.41 ± 1.83	6.52 ± 1.46	6.31 ± 2.11	
Repetition side steps (points)	6.11 ± 1.36	6.53 ± 1.63	5.74 ± 0.95	
20 m shuttle run (points)	5.74 ± 1.35	6.00 ± 1.20	5.50 ± 1.46	
50 m run	6.24 ± 1.90	6.68 ± 1.79	5.89 ± 1.94	
Standing jump (points)	4.52 ± 1.47	4.79 ± 1.52	4.29 ± 1.40	
Ball throw (points)	7.29 ± 1.77	8.03 ± 1.73	6.67 ± 1.57	
Ability of Mastication				Sex difference
Sugar elution rate (%)	61.6 ± 7.03	62.8 ± 6.90	60.5 ± 7.08	NS
Area (mm^2)	9.71 ± 4.94	9.73 ± 5.20	9.70 ± 4.78	NS
Max (Mpa)	114 ± 10.3	113 ± 10.8	115 ± 10.0	NS
Ave (Mpa)	47.1 ± 5.22	46.0 ± 3.70	48.0 ± 6.19	NS
Force (N)	450 ± 217	443 ± 228	456 ± 211	NS

NS, not significant.

Table 4. **Relationship between physical fitness, athletic ability survey and ability of mastication**

	Mean grip strength	Sit-up	Sit-and-reach	Repetition side steps	20 m shuttle run	50 m run	Standing jump	Ball throw
Sugar elution rate (%)	**0.28***	**0.28***	**0.32***	**0.29***	0.14	0.15	0.26	**0.29***
Area (mm^2)	0.02	−0.07	−0.03	−0.04	0.07	−0.10	0.06	0.14
Max (Mpa)	0.15	**0.32***	0.18	0.02	−0.02	0.19	0.15	0.15
Ave (Mpa)	−0.02	0.21	0.07	−0.08	0.07	0.20	0.19	−0.21
Force (N)	−0.01	−0.03	−0.03	−0.06	0.09	−0.05	0.11	0.12
Mean grip strength	–	0.23	0.50**	0.49**	0.22	0.23	0.32*	0.44**
Sit-up		–	0.32*	0.39**	0.48**	0.48**	0.52**	0.30*
Sit-and-reach			–	0.45**	0.26	0.36**	0.38**	0.33*
Repetition side steps				–	0.57**	0.40**	0.36**	0.50**
20 m shuttle run					–	0.72**	0.52**	0.35**
50 m run						–	0.49**	0.37*
Standing jump							–	0.30*
Ball throw								–

*$P < 0.05$; **$P < 0.01$.

Table 5. **Differences of ability of mastication based on physical fitness**

Physical Fitness	Sugar elution rate* (%) (mean ± SD)	Area (mm^2) (mean ± SD)	Max (Mpa) (mean ± SD)	Average (Mpa) (mean ± SD)	Force (N) (mean ± SD)
≧mean + 1 SD (n = 11)	66.5 ± 7.9	10.1 ± 3.7	116 ± 10.6	46.3 ± 4.4	463 ± 156
≦mean − 1 SD (n = 10)	57.0 ± 6.7	10.1 ± 4.4	108 ± 15.2	45.3 ± 6.2	461 ± 222

Physical Fitness = 34.4 ± 6.2 (mean ± SD).
*$P < 0.05$.

that in the group of 'I eat vegetables less than once a day'. It is suggested that the dietary behaviour of eating vegetable frequently developed the masticatory force by increasing the resistance of the teeth, which was provided at the time of biting vegetables. It has been postulated that the environment, in which children can eat vegetables frequently, is influenced by the degree of parents' interest in the balances of nutrients or meals. Thus, it is considered important to adjust the environment in which the children eat food and to inform the parents about the balanced diet. In addition, the result of relationship between the sugar elution rate and the degree of obesity supports the findings in a previous study (14). These results suggest that the ability of mastication is influenced by the dietary behaviour, and thus it is important to adjust the dietary behaviour to improve the ability of mastication.

Akao *et al.* (15) reported that the people who exercised more than three days per week tended to represent higher occlusal force than others. Fukai *et al.* (2) stated that the junior high school students, who had high occlusal force, represented superior ability in all items of physical fitness test. Furthermore, some previous studies revealed that the occlusal ability correlated with the stability and balance sense of body, fine motor skill, activity of body and fitness habits (16, 17). In addition, Churei (18) found that the maximal grip strength was augmented by the bite. However, some previous studies evaluated the ability of mastication in relation to the occlusal force and maximal occlusal force, and proved that these parameters did not affect the actual ability of mastication while eating food. This study evaluated the ability of mastication by chewing gum method, and this method could assess the actual ability of mastication while eating food. Accordingly, this study is the first to highlight the relationship between the actual ability of mastication while eating food and the physical fitness.

Yoshino *et al.* (19) focussed on the sugar elution rate, and reported that the ability of mastication correlated positively with the grip strength and fitness habits. This study revealed that the ability of mastication had positive correlations with the mean grip strength, sit-up, sit-and-reach, repetition side steps and ball throw, suggesting that the sugar elution rate while eating food correlated with the level of physical fitness. It is considered that repetition side steps and ball throw reflect agility; grip strength and sit-up reflect instantaneous power and sit-and-reach reflects flexibility in the physical fitness and athletic ability survey (20). Thus, the positive relationship between the sugar elution rate and these parameters suggests that the ability of mastication correlates with the basic physical strength, which reflects the physical fitness.

Conclusion

This study was designed to clarify the relationship between the ability of mastication and dietary behaviour, and between the ability of mastication and physical fitness. I assessed the sugar elution rate as an index of direct parameter of the ability of mastication and examined its relationship with the dietary behaviour and physical fitness, which was evaluated by the physical fitness and athletic ability survey of MEXT. This study revealed that the children who had high ability of mastication had high feeling of expectation to eating food, ate vege-

tables frequently and showed high score in the physical fitness and athletic ability survey. These results suggest that the ability of mastication positively correlates with the dietary behaviour and physical fitness.

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