

Association between occlusal force and physical functions in preschool children: a comparison of males and females

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Abstract. [Purpose] To determine and compare changes over time in the physical strength of male and female children aged 4–5 years by measuring physical functions such as occlusal forces. [Subjects and Methods] The occlusal force, weight, height, grip strength, standing long jump, ball throwing, timed up and go (TUG), and the 25-m run time were measured of 331 children to determine their physical strength. All the children understood and were capable of completing all tests. [Results] Occlusal force among male infants significantly correlated with all items except ball throwing. Stepwise multiple regression analysis independently associated occlusal force with grip strength. In contrast, occlusal force of female infants significantly correlated with all the tested items. Stepwise multiple regression analysis also independently associated occlusal force with grip strength and TUG in females. [Conclusion] Grip strength indicating upper-limb muscle strength correlated with occlusal forces in both male and female children, whereas TUG, balance and walking ability indicating muscle strength of the lower limbs, correlated with items relevant to everyday functions in female infants. These findings show that different factors are involved in the occlusal forces of male and female children.

Key words: Occlusal force, Physical functions, Preschool children

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INTRODUCTION

Eating is essential for humans to survive¹⁾, and it consists of taking food into the mouth, chewing (mastication), and swallowing. Various physical functions such as muscle strength are necessary to chew food. Nevertheless, the necessity and importance of chewing has not received adequate attention.

Occlusal force in children is affected by changes in the occlusal contact area. A small occlusal contact area for example, in children with dental carries or malocclusion, reduces occlusal force²⁾. Gaviao et al.³⁾ found that occlusal force was lower in children who eat soft foods than in those who eat foods that require chewing.

However, the development of occlusion in children varies and also differs according to the developmental status of the oral cavity⁴⁾. Du⁵⁾ and Ma⁶⁾ et al. surveyed associations be-

tween the occlusal state and motor function in children, and found obvious influences of lifestyle habits on both of them.

The Ministry of Education, Culture, Sports, Science and Technology⁷⁾ issued Physical Activity Guidelines for Japanese Preschool Children in 2012 to reverse a decrease in the physical strength of children that has persisted for about 20 years. The guidelines describe the need to ensure that preschool children engage in daily physical activities, but do not refer to measurements or surveys of physical functions or strength at that stage. Motor ability and development have been measured in many studies of primary school or older children, but few studies have investigated preschool children in Japan. Espenshade^{8, 9)}, Grassow¹⁰⁾ and Seils¹¹⁾ are some of the few who have studied preschool children in other countries.

The diet in modern Japan has changed, and the physical strength of children has annually decreased. The Ministry of Health, Labour and Welfare¹²⁾ has stated that various dietary problems among children, such as biased nutrition, skipping breakfast, obesity during childhood, and being underweight during puberty might generate lifelong health concerns, and this has recently received public attention.

Physical functions such as occlusal force in preschool children are important to measure, and the present status should be clarified and its course followed.

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This study compared the physical functions, including occlusal force, of male and female children aged 4 to 5 years, who could understand oral instructions, to clarify changes in physical strength using annual measurements.

SUBJECTS AND METHODS

The physical abilities, such as occlusal force, body weight, height, grip strength, standing long jump, and softball throw, timed up and go test (TUG), and 25-m run times of 331 children (male, $n = 173$; mean age, 5.5 ± 0.6 y; mean height, 111.4 ± 5.2 cm; mean body weight, 18.3 ± 2.2 kg; female, $n = 158$; mean age, 5.4 ± 0.7 y; mean height, 110.6 ± 5.3 cm; mean body weight, 18.4 ± 2.6 kg) who attended five local kindergartens and nursery schools between 2012 and 2014 were assessed. All of the children could understand and implement the tasks associated with the measure. The consent of the children's parents to the measurement of several aspects of their children's physical strength was obtained.

All parents received an explanation of the purpose, methods and content of this study. They were informed that the data generated would not be used for purposes other than this study, and that measures would be adopted to prevent leakage of personal information. Explanations were given verbally and in writing, that the participation of the children in this study was voluntary, and that refusal to participate would not result in repercussions. After the parents had provided written consent to their children's participation, this study proceeded under the approval of the Ethics Committee of Saga University (Approval ID, 26-1).

Maximal occlusal force was measured twice using the functional teeth (including prostheses) in the bilateral second deciduous molar areas using an Occlusal Force Meter GM10 (Nagano Keiki). The maximum values of both sides were analyzed.

The children were weighed without shoes and socks, while they stood still on the center of a weighing scale.

The height of the children was measured without shoes and socks while they stood upright with their back, buttocks and heels in contact with the vertical surface of a stadiometer, with their arms hanging down naturally at their sides, and with the chin slightly drawn back to maintain their head position.

The maximum grip strength of the dominant hand of the children was measured while they stood with both arms

hanging at their sides using a digital handgrip dynamometer (Takei Scientific Instruments, Niigata City, Japan), and the highest value (kg) was adopted. To avoid any imbalance due to the presence or absence of chewing during measurement, the children were instructed to close their mouths and grip the dynamometer while clenching their teeth¹³.

For the standing long jump, the children stood with their feet slightly apart behind a take-off line, bent both their knees and then jumped with both feet as far as possible. The shortest distance from the take-off line, the nearest mark made by the heels at landing, was measured in centimeters.

For the softball throw, the children stood with both feet behind a line with one foot forward, and threw a softball overarm as far as possible using their dominant arm without a run-up. Parallel lines (width, 6 m) were drawn at 1-m intervals, and the shortest distance from the throwing line to the site where the ball struck the ground was measured in centimeters. The subjects threw the ball twice in succession, and the longer distance was adopted.

The TUG test was performed as described by Shimada et al¹⁴). The children stood up from a chair, walked to a target 3 m ahead, turned and walked back to the chair, and sat down again. The amount of time (seconds) required to complete this task was measured. Each child sat on the chair in contact with the backrest and seat. Measurements started upon the verbal command, "go" and stopped when the buttocks regained contact with the chair. All timed values were measured using a digital stopwatch.

The 25-m run began from a standing start. A starter gave the instructions, "Ready", "Set", "Go", and the children started to run when they heard "Go". The amount of time required to reach the goal 25 m ahead was measured using a digital stopwatch.

Occlusal force and each physical function item were compared between the 173 boys and 158 girls using the unpaired t-test. Associations between occlusal force and other measured items were evaluated in males and females using Pearson's correlation coefficient. Items independently associated with occlusal force were identified using stepwise multiple regression analysis with occlusal force as the objective variable and body weight, height, grip strength, standing long jump, softball throw, TUG and the 25-m run times as explanatory variables for both males and females. All data were statistically analyzed using SPSS 16.0, and values of $p < 0.05$ were regarded as significant.

Table 1. Gender-related differences in physique and physical functions

	Males (N=173)	Females (N=158)	t-test
Body weight (kg)	18.3±2.2	18.4±2.6	
Height (cm)	111.4±5.2	110.6±5.3	
Occlusal force (kg)	290.4±111.2	268±104.7	*
Grip strength (kg)	7.6±2.2	6.9±2.3	**
Standing long jump (cm)	99.5±22.7	93.7±20.1	**
Softball throw (cm)	524.7±206.2	381.4±148.6	**
TUG (sec)	5.8±1.0	6.1±1.1	**
25-m run (sec)	6.5±0.7	6.9±1.8	**

Mean ± SD. * $p < 0.05$, ** $p < 0.01$

RESULTS

Table 1 shows the mean values and standard deviations of each measured item of the 173 boys and 158 girls, and the results of the t-test. Table 2 shows an analysis of simple correlations between occlusal force and each of the measured items of the boys and girls. The t-test revealed the boys showed significantly higher values for all of the items, except height and weight, than the girls.

The occlusal force of the boys significantly correlated with all items except the softball throw. Stepwise multiple regression analysis identified grip strength as a factor that was independently associated with occlusal force (standard regression coefficient, 0.47; $p < 0.01$; Table 3).

The occlusal force of the girls significantly correlated with all items. Stepwise multiple regression analysis independently associated grip strength and TUG with occlusal force; standard regression coefficients, 0.44 (0.01) and -0.19 ($p < 0.01$), respectively (Table 3).

DISCUSSION

This study evaluated associations between occlusal force and physical functions in preschool children in terms of grip strength, standing long jump, softball throw, and TUG and 25-m run times. Boys values for all of the physical function items were significantly higher girls. Palinkas et al.¹⁵⁾ reported that occlusal force was higher in males than in females in all age groups from 7 to 80 years. Miura et al.¹⁶⁾ also found a higher value for occlusal force in elderly male community-dwellers. The results of a longitudinal study by Peek et al.¹⁷⁾ suggested that gender was an important deter-

minant of occlusal force in elderly African-Americans living in farming villages. The findings of a higher occlusal force in the boys than in the girls, in the present study, is consistent with the association between the occlusal force and gender reported by these previous studies. Although Miura et al.¹⁶⁾ and Peek et al.¹⁷⁾ studied elderly individuals, whereas the present study assessed preschool children, gender-related differences were evident in this study, probably because the kinetic motions of occlusion involve the contraction of jaw-closing muscles and chewing with the upper and lower molars.

Multiple regression analysis with occlusal force as the objective variable revealed a significant partial correlation with grip strength in preschool boys, showing that occlusion force increases with grip strength. Since both occlusal force and grip strength are considered as static strength generated by isometric contraction, changes with the growth/development of the masticatory muscles and the muscles of the four limbs can be readily evaluated.

Johnson et al.¹⁸⁾ found age-related positive associations between the maximum occlusal force of the first molar and the grip strength of individuals aged 6–18 years. Kamegai et al.¹⁹⁾ also reported occlusal force increases with age. Maximum grip strength reportedly increases with age²⁾. Scammon²⁰⁾ reported that the nervous system grows rapidly after birth, reaching about 80% of the complexity of a fully mature adult by the age of 4–5 years. These studies suggest that the muscle strengths of both occlusion and grip increase with age despite individual differences, supporting the significant correlation between occlusal force and grip strength identified in this study. Multiple regression analysis using occlusal force as the objective variable showed significant partial correlations between grip strength and TUG in preschool girls. Occlusal force increased in parallel with increased grip strength, and the TUG time was shorter. A possible cause of the increased grip strength might be an age-related increase in overall muscle strength in both boys and girls.

Hirao et al.²¹⁾ found a significant correlation between the occlusal force and TUG time of elderly female community-dwellers, a finding echoed in the present results.

Based on the present findings, it seems that grip strength might be associated with occlusal force in preschool children. The association of masticatory ability and grip strength in both males and females was also reported by Yoshino et al.²²⁾. The correlation of occlusal force and TUG was associated in the preschool girls with lower muscle strength, balance, walking ability and functions of daily living. Thus,

Table 2. Analysis of simple correlations between occlusal force and physical functions in preschool children

	Males (N=173)		Females (N=158)	
Body weight	0.22	**	0.26	**
Height	0.20	**	0.23	**
Grip strength	0.47	**	0.51	**
Standing long jump	0.23	**	0.25	**
Softball throw	0.12	n.s.	0.27	**
TUG	-0.16	*	-0.32	**
25-m run	-0.29	**	-0.22	**

* $p < 0.05$, ** $p < 0.01$, n.s.: not significant

Table 3. Multiple regression analysis using the occlusal force of preschool children as the objective variable

	Males (N=173)			Females (N=158)			
	Standard regression coefficient	Standard error		Standard regression coefficient	Standard error		
Grip strength	0.47	3.5	**	Grip strength	0.44	3.11	**
				TUG	-0.19	6.23	**
Coefficient of determination (R^2)	0.22				0.28		

* $p < 0.05$, ** $p < 0.01$

factors affecting occlusal force in preschool children differ between boys and girls.

Cabrera et al.²³⁾ reported that decreases in occlusal force and grip strength are important risk factors that not only induce malnutrition, but also narrow the range of food selection, which obviously affects psychological status and reduces functionality and independence. Occlusal force mostly depends on the daily use of masticatory muscles²⁴⁾. Based on these previous findings, it appears that the Japanese diet is becoming softer and developmental issues, rather than a decrease in occlusal force itself, might pose a problem for preschool children. Hirao et al.²¹⁾ reported that occlusal force is associated with not only muscle strength and equilibrium but also with cognitive function among elderly community dwellers. Their study did not evaluate cognitive function in preschool children, but the immature development of occlusal force in preschool children might affect their cognitive function. Therefore, future studies are required to evaluate associations between occlusal force and cognitive function as well as physical functions in children.

The present study measured the occlusal force and physical functions of 313 preschool children. However, the results might not be applicable to all preschool children. Only a few studies have investigated occlusal force in preschool children, and longitudinal, long-term studies of larger groups of preschool children are needed to confirm the present results.

The present study could not measure cognitive function because the children became tired due to the length of time required to measure occlusal force and physical functions. Furthermore, cognitive function cannot be appropriately examined during a short period of time, because individual children significantly differ and a suitable examination has not yet been established. Thus, an appropriate method of evaluating cognitive function is needed to continue this study.

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