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The relationship between development of children's bodies and gravity center movement

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Abstract The relationship between the development of children's bodies and gravity center movement was studied. The subjects of this study were 61 children (30 boys, 31 girls) at nursery school. Foot-sole-prints were obtained using a stamp method and presence of foot arch formation was determined. The first measurement was taken in May 2003 and the second measurement was 6 months later. The children's physical functions were measured including standing height, body weight and foot length. In addition, the distance and the area of center of gravity movement when the subjects had their eyes opened and eyes closed were measured with automatic attitude analytical devices. Occlusal abilities were measured including occlusal contact area, average pressure and occlusal force with the Dental Prescale®. The male group showed a significantly wider occlusal contact area and a stronger occlusal force than the female group. A significant positive correlation was found between body height and occlusal contact area. A negative correlation was found between contact area and distance of BCG. A significant negative correlation was found between contact area and area of BCG. A significant difference was found between the eyes opened and eyes closed groups in the center of gravity movement for both children with formed foot arches and those without. The center of gravity movement of the foot arch formed group was less than that of the unformed group. A significant difference was found between the formed foot arch group and unformed foot arch group with regard to the improvement in gravity center movement based on the change in results from the first measurement to the second.

Key words
Foot arch,
Gravity center movement,
Nursery school,
Occlusal contact area,
Occlusal force

Introduction

With the development of science and technology, people use more and more machines in their lives and have become more dependent on them. In developed countries like Japan, these conditions are displayed significantly. People are not getting sufficient exercise and their physical functions and forms appear to be degenerating[1], including balance functions and occlusal functions[1,2,5], and forms of foot arches and jaws. Recently, "Dangerously full foot arch" and "fragile jaw" have been reported as having arisen from these degenerative functions[1,11].

Prevalence of dental caries in young children and schoolchildren has recently decreased[4], but abnormal relations of dental arches and malocclusion were found to have increased[3,9,10]. In the clinic, we find patients with poor oral conditions or malocclusion who also have some pernicious habits or poor posture. Usually, these results prompt us to pay special attention to something outside the dental field[11]. Thus, this study was conducted to examine the relationships among a child's occlusal ability, balance ability and formation of foot arch.

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Table 1 Physical and mental development states of children

	4 years old	5 years old	6 years old
Body weight (kg)	16.1 ± 2.3	17.1 ± 2.2	19.8 ± 3.7
Standing height (cm)	101.2 ± 5.0	104.6 ± 5.4	111.2 ± 4.9
Foot length (cm)	16.0 ± 1.0	16.1 ± 1.0	17.0 ± 1.0
KAUP index	15.7	15.6	16.0

Table 2 Japanese physical strength standard

	4 years old	5 years old	6 years old
Body weight (kg)	17.0 ± 2.2	18.5 ± 2.6	21.9 ± 2.9
Standing height (cm)	103.8 ± 4.9	108.6 ± 4.8	113.9 ± 4.7
Foot length (cm)	15.8 ± 0.8	16.7 ± 0.9	17.6 ± 0.9
KAUP index	15.8	15.6	16.7

Materials and methods

Subjects

Sixty-one nursery school children, ages 4 to 6 years with cooperative behavior were the subjects of this study. Informed consent was acquired from the children's parents or guardians. The children's (30 boys, 31 girls) average body weight, standing height, and foot length were recorded before measuring their gravity center. The KAUP index was obtained through calculation. The results (Table 1) conform to the Japanese physical strength standard values (Table 2). Thus, we can use the data as a standard, which is representative of the larger population.

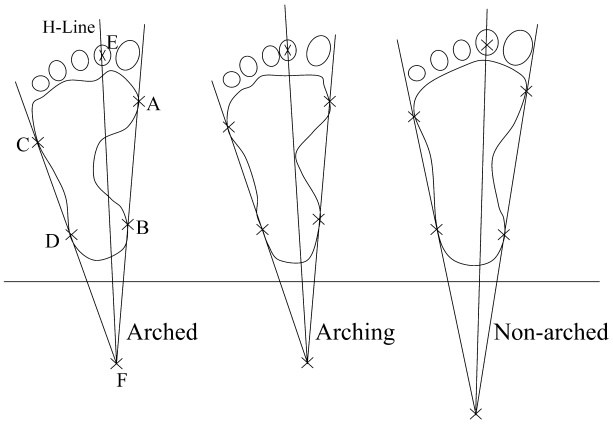

Fig. 1 Foot arch pattern

Measurement of foot arch

The subject's foot sole print and the gravity center were measured twice using the Stamp method, the first time in May 2003 and the second time 6 months later. In this method, India ink and white drawing were used. The subjects were asked to sit down on a chair. Both feet were placed on the cloth soaked with India liquid ink. Then, the imprints of both feet were made simultaneously on the white drawing paper, ensuring the feet were parallel to each other and distance between them was 10 cm. The children were told to stand still for 2 seconds. Subsequently, they were asked to sit down again, the clinician released both feet from the paper. They were once again told to stand with two feet simultaneously on a new drawing paper to obtain a second print. The method used in the detection of foot arch and the conditions were based on the standards set by the Japan Society for Equilibrium Research (Fig. 1). The subjects were divided into 2 groups according to their foot sole prints: Group 1 (n = 48) the formed foot arch group which included arched and arching feet; and Group 2 (n = 13) the unformed foot arch group which included non-arched and non-arching feet.

Measurement of occlusal contact area and average bite pressure

For measurement of occlusal ability characteristics, an S size film of the Dental Prescale® was used (50H type R, Fuji Film®). The measurement was based on standards from previous studies. The subjects were asked to practice before the measurements were taken. Subsequently, the film was prepared and placed in the subject's oral cavity for 3 seconds

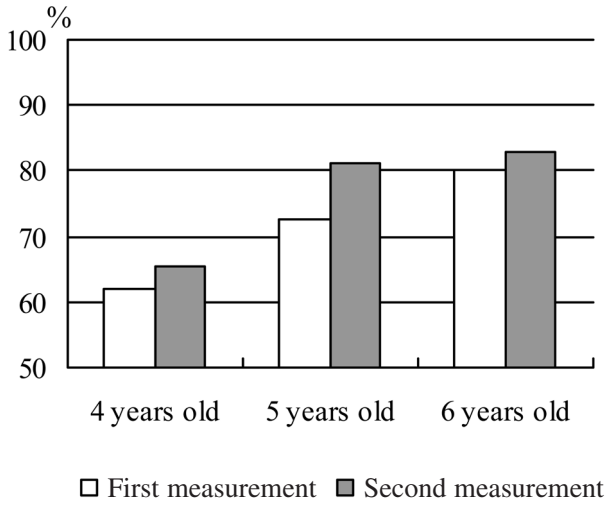

Fig. 2 The formation ratio of feet arch

making sure of correct placement. The measurement was performed 3 times for each subject and the average was taken. The used films were kept in a cool, dark place before film analysis.

For a measurable quantity analysis system, the Fuji Film Occluzer® (Dental occlusion pressure graph FPD-705) was used. This system can automatically obtain the contact area, average pressure, maximal pressure, and occlusal force.

Measurement of gravity center

The system consisted of a dynamometric platform (VTS-311 EGG 2000v, Patella Co., Japan) and a computer analysis system (Microsoft® Windows® 98, IBM®). This system can measure and calculate the body's center of gravity (BCG) automatically. The BCG is a vertical projection of the body's mass center (gravity center). It directly reflects the gravity center movement. The system records the movement of BCG for 10 seconds in each phase. The computer can calculate the total distance and area that the BCG moved and the average position of the BCG. We evaluated only the average position of BCG in this research to show the tendency of the gravity center movement as the standing posture changes. Furthermore, measurement methods and conditions were set after referencing the Japan Society for Equilibrium Research and previous studies. An apparent mark was recorded based on the measurement taken while subject stood in Romberg position and gazed forward at a BCG platform located 2 meters in front. Subsequently, an eye-mask was used to cover the subjects' eyes. The gravity center was then measured and the distance of center of gravity movement, the movement locus at each 10 seconds phase was recorded 5 times: 3 times with eyes opened and 2 times with eyes closed.

Statistical analysis

All data were analyzed with SPSS 11.01 for Windows statistical package.

ANOVA test was used to examine the difference among the 3 groups (ages 4, 5, and 6) and 2 groups (eyes opened and closed); Pearson correlate analysis was used between the occlusal abilities and gravity center movement; The Student's *t*-test, Mann-Whitney U-test, and Krusal Wallis test were used to examine the differences in the contact areas, bite forces and mean pressures between the subjects' two sides or three sides.

Results

Foot arch formation ratios for 4, 5, and 6-yr old children taken in May and were 61.9%, 65.5% and 72.6%, respectively, and in November 81.0%, 80.3% and 82.9%, respectively. The average of all of the subjects' foot arch formation ratios' was 76.5% when the measurement of occlusal ability and gravity center movement was taken (Fig. 2). Foot arch formation ratios increased for ages 6 months and older.

For occlusal ability, the average occlusal contact area was found to be 10.18 mm^2 and the average

Table 3 Occlusal abilities and sex

	Male group (n = 30)	Female group (n = 31)	*P*
Contact area (mm^2)	11.14	9.22	0.021[2)]
Average pressure (MPa)	39.26	39.34	N.S.[1)]
Maximal pressure (MPa)	103.32	104.11	N.S.[2)]
Occlusion force (N)	444.17	378.49	0.045[1)]

Table 4 Occlusal abilities and age

	4 yrs group (n = 21)	5 yrs group (n = 21)	6 yrs group (n = 19)	*P*
Contact area (mm^2)	10.13	10.24	10.17	N.S.[3)]
Average pressure (MPa)	38.23	39.96	39.71	0.049[4)]
Maximal pressure (MPa)	100.13	104.30	106.73	N.S.[3)]
Occlusion force (N)	393.48	410.70	430.02	N.S.[4)]

Table 5 Gravity center movement and foot arch

		Formed group (n = 48)	Non-formed group (n = 13)	*P*
Eyes opened	Distance of BCG (cm)	29.1	32.0	0.001[2)]
	Area of BCG (cm^2)	8.9	10.7	0.005[2)]
	Pressure area (cm^2)	93.48	92.49	N.S.[1)]
Eyes closed	Distance of BCG (cm)	34.9	37.6	0.021[2)]
	Area of BCG (cm^2)	12.4	15.8	0.001[2)]
	Pressure area (cm^2)	95.96	98.71	N.S.[1)]

[1)] Student's *t*-test, [2)] Mann-Whitney U-test, [3)] Krusal Wallis test, [4)] ANOVA
N.S.: not significant, n = 61

occlusal pressure 39.30 MPa. The maximal occlusal pressure was 103.72 MPa, and occlusal force was 410.79 Mpa. The male group showed a significantly wider occlusal contact area and a stronger occlusal force than the female group (Tables 3 and 4).

For gravity center movement with eyes opened, the distance of gravity center movement (distance of BCG) was found to be 29.68 cm (n = 61) and the area of gravity center movement was 9.28 cm^2. The foot-sole pressure area was 93.27 cm^2. With eyes closed, the distance of gravity center movement was 35.48 cm, the area of gravity center's movement was 13.13 cm^2, and foot-sole pressure area was 96.54 cm^2. A significant difference in the center of gravity movement was found between groups of formed foot arch and non-formed with both the eyes opened and eyes closed (Table 5).

Among foot arch formation, occlusal ability, and gravity center movement, body height had a significant positive correlation with contact area (Pearson correlation $P = 0.038$) (Table 6). A significant positive correlation was found between average pressure and body height (Pearson correlation $P = 0.043$). A negative correlation was found between contact area and distance of BCG (Pearson correlation eyes opened $P = -0.028$ and eyes closed $P = -0.077$). A significant negative correlation was found between contact area and area of BCG (Pearson correlation, eyes opened $P = -0.013$ and eyes closed $P = -0.041$) (Table 7). The improvement of BCG increased with age when the measurements were made 6 months later (Table 8). A significant difference was found in the improvement of gravity center movement from first measurement to the second measurement between the formed foot arch group and non-formed foot arch group (Table 9).

Table 6 Occlusal abilities and physical and mental development

	Body weight (kg)	Standing height (cm)	Foot length (cm)
Contact area (mm^2)	N.S.[1)]	0.038[1)]	N.S.[1)]
Average pressure (MPa)	N.S.[1)]	0.043[1)]	N.S.[1)]
Maximal pressure (MPa)	N.S.[1)]	N.S.[1)]	N.S.[1)]
Occlusion force (N)	N.S.[1)]	N.S.[1)]	N.S.[1)]

Table 7 Occlusal abilities and gravity center movement

		Contact area (mm^2)	Average pressure (MPa)	Occlusion force (N)
Eyes opened	Distance of BCG (cm)	−0.028[1)]	N.S.[1)]	N.S.[1)]
	Area of BCG (cm^2)	−0.013[1)]	N.S.[1)]	N.S.[1)]
Eyes closed	Distance of BCG (cm)	−0.077[1)]	N.S.[1)]	N.S.[1)]
	Area of BCG (cm^2)	−0.041[1)]	N.S.[1)]	N.S.[1)]

[1)] Correlation coefficient: Pearson,
N.S.: not significant, n = 61

Table 8 Gravity center movement and age

		4 yrs group (n = 21)	5 yrs group (n = 21)	6 yrs group (n = 19)	*P*
Eyes opened	Distance of BCG (cm)	30.6	29.2	29.2	0.001[2)]
	Area of BCG (cm^2)	10.7	8.7	8.4	0.005[2)]
	Pressure area (cm^2)	90.81	92.15	97.22	N.S.[1)]
Eyes closed	Distance of BCG (cm)	38.1	35.2	32.9	0.001[2)]
	Area of BCG (cm^2)	16.1	12.1	11.0	0.005[2)]
	Pressure area (cm^2)	92.88	96.75	100.37	N.S.[1)]

Table 9 Gravity center movement in twice measurement

			First measurement	Second measurement	*P*
Formed group (n = 48)	Eyes opened	Distance of BCG (cm)	32.8	27.9	<0.001[2)]
		Area of BCG (cm^2)	10.2	8.9	0.047[2)]
	Eyes closed	Distance of BCG (cm)	36.4	34.9	<0.001[2)]
		Area of BCG (cm^2)	14.7	12.4	0.005[2)]
Unformed group (n = 13)	Eyes opened	Distance of BCG (cm)	31.4	31.0	<0.001[2)]
		Area of BCG (cm^2)	11.8	10.7	0.035[2)]
	Eyes closed	Distance of BCG (cm)	37.9	37.6	<0.001[2)]
		Area of BCG (cm^2)	16.7	15.8	0.002[2)]

[1)] Student's *t*-test, [2)] Mann-Whitney U-test,
N.S.: not significant, n = 61

Discussion

The study, explored the correlation between occlusal and whole body conditions with respect to gravity center movement by analyzing variations while the body was in a straight standing position. The system in this study consisted of a dynamometric platform and a computer analysis system that automatically measured and calculated the center of gravity (BCG). The BCG is a vertical projection of the body's gravity center, directly reflecting gravity center movement. We evaluated only the average position of BCG in this research to show the tendency of the gravity center movement as the standing posture changed. The measurement methods and conditions were based on standards set by the Japan Society for Equilibrium Research and previous studies[2–5]. For all data, the average value of 5 measurements was used. A significant difference was found between the measurements of the center of gravity movement in the eyes opened and eyes closed groups. This finding is in agreement with those in previous studies[4,7,8]. The subjects of the previous studies were adults, and this may explain a significant difference between the measurements of gravity center movement obtained with eyes opened and eyes closed for all age groups.

For foot arch formation and gravity center movement, the center of gravity movement of the formed foot arch group was less than the unformed group. A significant difference was found, and this does not agree with the findings of previous studies[1,4]. There was a significant difference between the improvement in the gravity center movement from the first measurement to the second measurement of the formed foot arch group and unformed foot arch group. This is the first time this type of study was done. The results suggest that foot arch formation is an important factor in balance function, and this was not in agreement with previous studies[17,18].

Methods of detection of foot arch and conditions were based on the standards set by the Japan Society for Equilibrium Research and previous studies[6–8]. Foot arch formation rate was slightly higher than that of the Japanese average baseline[3].

For the results of occlusal ability measurement, the male group showed a significantly wider occlusal contact area and a stronger occlusal force than the female group. These results were in agreement with some previous studies[4,9,10,12]. A significant positive correlation was seen between body height and occlusal ability. The taller group showed stronger average pressure than the shorter group. Some previous studies reported that children with poor oral conditions or malocclusion also had poor balance functions. Recently, some researches reported that relationship between occlusal ability and children's feet[11], in this time found a negative correlation between gravity center movement and occlusal ability, a positive correlation was seen between development of foot arch and gravity center movement, thus the relationship exist between gravity center movement, occlusal ability and development of children's bodies. In this study, contact area for the 6 year old group was less than the 5 year old group, and this result does not agree with that of previous studies[13–16]. The reason maybe that of dental caries of deciduous teeth or premature loss of primary teeth lessens the occlusal area at age 6.

Conclusion

The relationship between development of children's body and gravity center movement were studied. The following are conclusions from the study:

1. The male group showed a significantly wider occlusal contact area and a stronger occlusal force than the female group; a negative correlation was found between contact area and distance of BCG; a significant negative correlation was found between contact area and area of BCG. A significant positive correlation was observed between body height and occlusal ability: the taller group showed stronger average pressure and contact area than the shorter group.
2. A significant difference in the center of gravity movement was seen between the group with eyes opened and that eyes closed. The distance and area of gravity center movement were less for the group with eyes opened than eyes closed, in both formed and unformed foot arch groups.
3. The formed foot arch groups' center of gravity movement was less than that of the unformed group in both distance and area. The improvement in the gravity movement between the first and the second measurements for the unformed foot arch group was less than the formed foot arch group.

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