

Relationship between Untouched-Toes and Heel Load in Preschool Children

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Although the number of children with untouched-toes, which do not touch the floor while standing, is increasing in Japan, the cause of untouched-toes and its effect on the body have been rarely investigated. This study aims to examine the relationship between untouched-toes and heel load in preschool children. The subjects were 691 preschool children aged 4 - 6 years (328 boys and 363 girls). The contact surface area of the soles of the feet was pictured to evaluate the untouched-toes. The posterior foot pressure ratio in both feet was used to evaluate the heel load. During the entire childhood period, the posterior foot pressure ratio was significantly larger in children with over two untouched-toes than in children without untouched-toes for the left foot, and in children with over two untouched-toes than in children without untouched-toes and with one untouched-toe for the right foot. In addition, this ratio was significantly larger in children aged 4 years than in children aged 6 years for the left foot, and in children aged 4 years than in children aged 5 and 6 years for the right foot. In conclusion, children with over two untouched-toes tend to have greater heel load than children without untouched-toes.

Keywords: Foot Shape; Untouched-Toes; Foot Pressure Load; Heel Load; Posture; Children

Introduction

Untouched-toes are the toes that do not touch the floor during normal standing. Recently, it has been reported that the number of children with untouched-toes is increasing in Japan (Harada, 2001; Uchida et al., 2001; Matsuda et al., 2009, 2011a). Toes are an important component in supporting the body and play a central role in maintaining the body's balance when standing and initiating walking movements (Chou et al., 2009). Considering the role of toes, untouched-toes may have a negative effect on the body and physical activity. However, the cause of untouched-toes and its effect on the body have been rarely investigated.

Physique, physical fitness, balance ability, shoes, heel load, exercise quantity, and usage frequency of toes have been noted as factors related to untouched-toes (Harada, 2001; Uchida et al., 2001). Previous examination of the relationships between untouched-toes and physique, physical fitness, and balance ability indicates that there is little relationship between these three factors (Chou et al., 2009; Matsuda et al., 2010, 2011b). The relationship between untouched-toes and the quantity of outdoor exercise has also been examined, and it was reported that children who belonged to a nursery with more outdoor exercise had fewer cases with untouched-toes.

Uchida et al. (2002) noted that the heel load, in which the center of gravity is in a posterior position, is a primary reason for untouched-toes and Harada (2001) pointed out the same as

one of the reasons for untouched-toes. The magnitude of toe pressure while standing is affected by the change of the position of the center of gravity; the more posterior the position is, the smaller the toe pressure becomes (Fujiwara et al., 1984). Hence, there may be a relationship between the untouched-toes and heel load; however, this relationship has been rarely examined. This study aims to examine the relationship between the untouched-toes and heel load in preschool children.

Methods

Subjects

The subjects consisted of 691 preschool children aged 4 - 6 years (328 boys and 363 girls). **Table 1** shows the number of subjects and their physical characteristics. Children were recruited from two kindergartens located in Gifu and Yamagata cities, Gifu, Japan. The population of Gifu (city) and Yamagata is approximately 410,000 and 30,000, respectively.

The purpose and procedure of this study were explained to the subject's parents in detail and informed consent was obtained before the measurement.

In addition, the consent of the participants for the measurement was obtained at the time of measurement. This experimental protocol was approved by the Ethics Committee on Human Experimentation of Faculty of Human Science, Kanazawa University (2012-05).

Table 1.
Number of subjects and their physical characteristics.

			Age-4	Age-5	Age-6	Total
		n	127	101	100	328
Boys	Height	MEAN	102.8	109.3	115.4	108.6
	(cm)	SD	4.1	4.7	4.7	6.9
	Body mass	MEAN	15.7	16.9	19.0	18.8
	(kg)	SD	1.6	1.8	2.4	2.8
		n	145	127	91	363
Girls	Height	MEAN	102.3	109.3	114.0	107.7
	(cm)	SD	4.3	4.1	6.3	6.8
	Body mass	MEAN	15.4	16.7	18.9	18.4
	(kg)	SD	1.4	2.0	2.4	2.7

Measurement Methods

Anterior-Posterior Foot Pressure Ratio

The heel load was evaluated by calculating the anterior-posterior foot pressure ratio. This ratio refers to the pressure distribution between the anterior and posterior parts of the foot. In the case of the left foot illustrated in **Figure 1**, the anterior and posterior ratios are 26% and 74%, respectively. The line dividing the foot into the anterior and posterior parts was formed at the center of the foot length, which is defined as the distance from the back of the heel to the front of the longest toe.

A Footview Clinic (Nitta, Japan) was used to measure the anterior-posterior foot pressure ratio. This measurement device can calculate the anterior-posterior foot pressure ratio of each foot using all foot pressures obtained from the area of the foot that is in contact with the device while the subject is in a standing position (**Figure 1**). For the purposes of the present study, the sampling frequency was 20 Hz.

The anterior-posterior foot pressure ratio was measured using a previously described method (Matsuda et al., 2012; Matsuda & Demura, 2013). The subjects stood barefoot on the Footview Clinic measurement device, with their feet 5 cm apart and their hands relaxed at the side of the body. Before the measurement of the anterior-posterior foot pressure ratio, a stationary picture of the contact area of the sole of the foot was recorded using the device to obtain their foot length, which was necessary for analysis. Because of the fact that some children were unable to touch their toes, a tester pushed the subject's toes downward temporarily during the recording of the stationary picture. Subsequently, a 10-s measurement was initiated after the tester confirmed that the child's posture was stable. The subjects were instructed to look at a mark located at eye-level and to remain still as long as possible during the measurement. Each subject was measured three times.

In addition, it is important to note that some young children could not maintain a stable posture or continuously keep their eyes on the mark as directed. Such children were excluded from this study in advance.

Contact Surface Area of the Sole

A pedoscope (Sakamoto, Japan) was used to record the contact surface area of the soles of the subjects' feet, which was used for the analysis of untouched-toes. The subjects stood in the same posture as that for the measurement of the anterior-

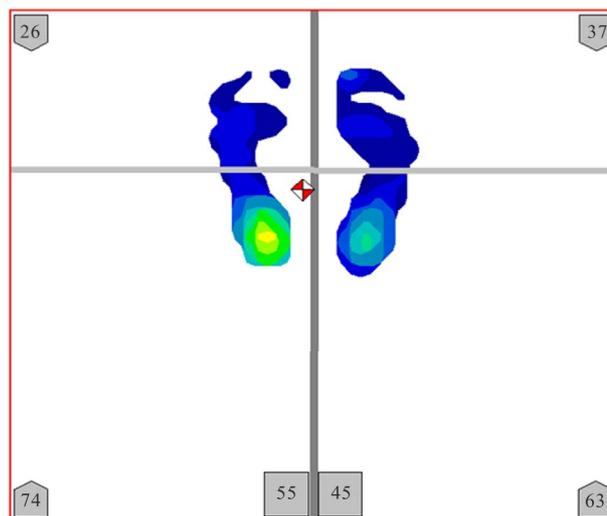


Figure 1.
Anterior-posterior foot pressure ratio.

posterior foot pressure ratio. After a tester confirmed the subject's postural stability, a picture of the contact surface area of the soles of their feet was recorded. Each subject was sequentially measured five times while standing. Untouched-toes are defined as the toes that did not emerge in more than four pictures among the five recorded pictures.

Evaluation Variables

The posterior foot pressure ratio was selected as a variable to evaluate the heel load, and the mean of a 10-s measurement was used for analysis. It was reported in a previous study that the second and third trials have high reliability (Matsuda et al., 2012); therefore, they were used for this analysis.

The number of untouched-toes in both feet was selected as a variable to evaluate the untouched-toes. Three groups were established on the basis of the number of untouched-toes: a group without untouched-toes, a group with one untouched-toe, and a group with two or more untouched-toes. When a group with three or more untouched-toes was established, the number of the subjects in this group was extremely small in comparison with the other groups. Hence, only the above three groups were formed.

Statistical Analysis

Trial-to-trial reliability was examined using intraclass correlation coefficient (ICC). A two-way analysis of variance (ANOVA) was used to test the mean differences among the groups according to different number of untouched-toes and age (4 - 6 years) in the posterior foot pressure ratio. Owing to the fact that a significant age difference in the posterior foot pressure ratio of preschool children has been documented (Matsuda et al., 2012), the factor of age was set as an independent factor. If a significant difference was found in the main effect or interaction, Tukey's honestly significant difference test was used for a multiple comparison test. In addition, because there were no sex differences in the number of untouched-toes and posterior foot pressure ratio in this study as well as previous studies (the number of untouched-toes: $t = 1.77, p = .08$; foot pressure ratio (right foot): $t = -.89, p = .38$; (left foot): $t = .25, p = .80$) (Matsuda et al., 2009, 2012), the combined data of boys

and girls were used for the above analysis. When a significant difference was found, the effect size was calculated to examine the size of the mean difference. The level of statistical significance was set at $p < .05$.

Results

Intraclass correlation coefficients (ICC) for the posterior foot pressure ratio were .88 and .86 for the left and right feet, respectively. **Table 2** shows the results of the two-way ANOVA and a multiple comparison test for the posterior foot pressure ratio. Significant differences among the means of the groups according to different number of untouched-toes and age were found in both feet. The posterior foot pressure ratio was significantly larger in children aged 4 years than in children aged 6 years for the left foot and in children aged 4 years than in children aged 5 years and 6 years for the right foot. The effect sizes were .36 for the left foot, and .22 in children aged between 4 and 5 years and .44 between 4 and 6 years for the right foot. Regarding the number of individuals with untouched-toes, the posterior foot pressure ratio was significantly larger in the group with over two untouched-toes than in the group without untouched-toes for the left foot and in the group with over two untouched-toes than in the groups without untouched-toes and with one untouched-toe. The effect size was .32 for the left foot, and .39 between the groups with over two untouched-toes and the group without untouched-toes for the right foot, and .33 between the groups with two untouched-toes and the group with one untouched-toe for the right foot.

Discussion

Matsuda et al. (2012) reported that the ICC between the second and third trials was high, with a value of .85 for the anterior-posterior foot pressure ratio in preschool children. This was consistent with the result in our study (.88, .86). Hence, the reliability of data used in this study is considered to be high.

Although the heel load has been noted as one of the factors related to the occurrence of untouched-toes (Harada, 2001;

Uchida et al., 2002), the relationship between them has not been examined. This study evaluated the heel load by calculating the anterior-posterior foot pressure ratio on the basis of the line that was established at the center of the foot length and examined the above relationship. During the entire childhood period, the posterior foot pressure ratio was significantly larger in children with over two untouched-toes than in children without untouched-toes and with one untouched-toe. Therefore, it is considered as one of the reasons of this result that the load of the toes decreased largely by having over two untouched-toes.

In addition, posture may be related to the present result. Fujiwara et al. (1984) examined the relationship between the anterior-posterior position of the center of gravity and toe pressure when posture changed from posterior inclination to anterior inclination. As a result, it was reported that the more anterior a posture was, the more anterior the position of the center of gravity was and the larger the toe pressure was. Hence, the posture of children with over two untouched-toes may be of a more posterior inclination than that of children without untouched-toes. A posterior inclination in the standing posture induces an increase of muscle activity in the tibialis anterior muscle, which contains more fast muscle fibers, and is considered unfit for postural maintenance. In addition, it is considered that a posterior inclination imposes an inappropriate burden on other antigravity muscles and has a negative effect on postural maintenance. The deterioration of posture is noted as a physical problem of modern young children in Japan (The national network of physical and mental health in Japanese children, 2009). Untouched-toes may have some relationship with postural inclination and the problem regarding postural deterioration. In future studies, it will be necessary to examine the above problems.

Matsuda & Demura (2013) reported that the posterior foot pressure ratio decreases with age in young children. The present result had a tendency similar to the above previous study. Further, in studies that examined an age-related change in the anterior-posterior position of the center of gravity, it was reported that the position moves anteriorly from childhood to adulthood

Table 2. Results of the two-way ANOVA and a multiple comparison test for the posterior foot pressure ratio.

		Age-4			Age-5			Age-6			Two-way ANOVA			Tukey's HSD (ES)	
		0 U-toes	1 U-toe	Over 2 U-toes	0 U-toes	1 U-toe	Over 2 U-toes	0 U-toes	1 U-toe	Over 2 U-toes	Age	Number of U-toes	Interaction		
	n	103	65	104	105	49	74	72	50	69					
The posterior foot pressure ratio in the left foot	M	70.8	69.1	73.0	68.4	69.6	71.6	63.7	69.4	69.5	F	5.31	7.29	1.97	Age-4 > Age-6 (.36)
	SD	10.1	12.0	10.4	12.1	11.0	10.3	12.4	11.6	9.8	p	.01*	.00*	.10	over 2 U-toes > 0 U-toes (.32)
The posterior foot pressure ratio in the right foot	M	68.4	68.6	72.2	66.3	65.5	70.0	61.1	65.4	67.9	F	9.64	10.84	.90	Age-4 > Age-5, Age-6 (.22, .44)
	SD	11.7	11.9	10.2	13.2	10.5	9.8	14.2	12.9	10.0	p	.00*	.00*	.46	over 2 U-toes > 1 U-toe, 0 U-toes (.39, .33)

Note: U-toe: Untouched-toe, M: Mean, SD: Standard deviation, * $p < .05$, ES: Effect size.

(Kojima & Takemori, 1980; Usui et al., 1995). Hence, it is considered that children with over two untouched-toes had a different tendency from general ones on the development process of foot pressure.

In this study, three groups according to the number of untouched-toes were formed because of the limit of the number of subjects. Considering the present results, there is a possibility that the greater the number of untouched-toes is, the more marked the tendency of heel load becomes. In addition, it has been reported that an untouched-toe occurs predominantly in the fifth toe (Matsuda et al., 2009). If a group having over three untouched-toes is formed, the effect of the number of untouched-toes on the heel load may become notable because it comprises a group of children with untouched-toes other than the fifth toe. In future studies, an examination similar to the present study will be necessary after increasing the number of subjects and establishing a group with over three untouched-toes. In addition, the effect of untouched-toes on the heel load may differ by the part of the untouched-toes. Although the above effect could not be examined in this study because of the limit of the number of subjects, it will be necessary to examine the above effect in future.

Although the relationship between the untouched-toes and heel load was examined in this study, the movement mass and type of shoes worn have also been noted as factors related to the occurrence of untouched-toes (Harada, 2001; Uchida et al., 2002). To clarify the cause of untouched-toes and its effect on the body, it will be necessary to examine the above problem.

Conclusion

In conclusion, this study examined the relationship between the untouched-toes and heel load by studying 691 preschool children (328 boys and 363 girls) aged 4 - 6 years. Children with over two untouched-toes have heel loads higher than children without untouched-toes. Because the posterior foot pressure ratio decreases with age in young children, the heel load related to the untouched-toes may not be desirable in terms of age-related change of foot pressure.

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