

Incidence of floating toe and its association with the physique and foot morphology of Japanese children

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Abstract. [Purpose] Physical development, foot morphology, and toe contact of children aged 3 to 5 years were assessed in order to investigate the relationships between body and foot morphology and the incidence of the condition known as “floating toe”. [Subjects] A total of 198 children, aged 3 to 5 years old, participated in this study. [Methods] Height and weight were measured for body morphology, and foot length and width were measured for foot morphology. Footprint images were taken to calculate the number of floating toes. Information about the children’s height and weight at birth, and the time of starting to walk was obtained from their guardians. [Results] At least one floating toe was observed in 87.7–98.7% of the children depending on their ages. The fifth toe was most commonly affected, occurring in 74.2% of the study population. Among the body and foot morphology parameters, only weight at birth showed a significant but very weak correlation with the number of floating toes. [Conclusion] There was a high incidence of floating toe among the children, with the fifth toe most commonly affected. Floating toe weakly but significantly correlated with weight at birth, but did not correlated with other measures of physique at birth, physical development, or the time of starting to walk.

Key words: Foot morphology, Physical development, Floating toe

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INTRODUCTION

With its complex anatomical structure, the foot plays a vital role in supporting body weight, absorbing shock, and moving the body forward when walking^{1–3)}. The toes also have the function of distributing load when walking⁴⁾. The feet grow significantly during infancy^{5, 6)} and have even been reported to develop before height⁷⁾. Infancy is a period of remarkable physical development and is also an important period in terms of foot development^{5, 8)}.

In recent years, there have been occasional reports of “floating toe”, a condition that does not involve pain or deformity in which the toes do not make contact with the ground when standing³⁾. In adults, the condition reportedly occurs as a result of surgery^{9, 10)}. Smith and Bernbach classified the condition into “floating toe” and “hammer toe”¹¹⁾, with the former caused by decreased flexor strength due to instability of the metatarsophalangeal joint. In adult cases of

floating toe, grip strength and ability to move forward are diminished¹²⁾.

The onset age of floating toe remains unclear. Although there have been no studies reported in English, a study of Japanese children reported a high incidence of this condition¹³⁾. This incidence increased in the 2000s than in the 1980s¹⁴⁾ and is suggested to be affected by how much a child plays outdoors.

The purpose of this study was to investigate the incidence of the condition known as “floating toe” and its relationships between body and foot morphology of Japanese children aged 3 to 5 years.

SUBJECTS AND METHODS

The subjects were 198 Japanese children (102 boys and 96 girls) aged 3 to 5 years (Table 1). Enrollment criteria were no morphological deformities of the feet and no past medical history of the feet. Children with neurological or orthopedic disorders affecting foot morphology were excluded. The children all attended the same kindergarten, and the measurements were performed in the same environment.

Before commencing the measurements, the nature and methods of the study were fully explained to the children and their guardians, and verbal consent from the children and written consent from their guardians were obtained, in-

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Table 1. The number of the subjects and their physical characteristics

Age (yr)	Total (N)	Boys (N)	Girls (N)	Month age (yrs) (M, mean±SD)	Height (cm) (cm, mean±SD)	Weight (kg) (kg, mean±SD)
3	57	30	27	41.6±2.3	95.8±3.9	14.4±1.5
4	62	32	30	54.3±3.2	102.9±4.3	16.9±2.1
5	79	40	39	65.6±3.6	108.8±4.7	18.4±3.0
Total	198	102	96	55.1±10.3	103.2±6.8	16.7±2.9

dicating their willingness to participate in the study. In order to mitigate the burden of repeated measurements, children were able to withdraw from the study part way through. The study was conducted with the prior approval of the Ethics Committee of Saitama Prefectural University.

Physical characteristics and foot morphology were measured, footprint images were taken, and a questionnaire was administered. All measurements were conducted between 8:00 and 10:00 a.m. to minimize the effect of circadian variation. Moreover, one tester conducted all measurements to eliminate inter-observer error.

The physical characteristics measured were height and weight. For foot morphology, foot length and width were measured using a sliding scale (Junior Brannock Device, The Brannock Device Inc., NY, USA). Foot length was measured as the distance from the second toe to the center of the heel, and foot width was measured as the straight line from the first MTP joint to the head of the fifth metatarsal orthogonal to foot length. Measurements were performed with the subjects in the standing position.

Footprint images were taken using an ink foot printer (Pedoprint foot imprinter set, Bauerfeind Co., Ltd., Thüringen, Germany). The foot imprinter consists of a rubber mat with a net underneath that is impregnated with ink. A piece of paper is placed beneath the net, and a footprint impression is made by having the subject stand on the rubber mat. Good images were not obtained for several of the 3-year-old children when standing, so they were verbally instructed to sit with their feet on the rubber mat and then to stand up still while looking at a point 2 meters ahead for 5 seconds until a good image was obtained. Footprint images were taken of both feet. Assessment of toe contact was done based on these footprint images. Toe contact was assessed as 1 point if a toe imprint was even slightly visible and 0 points if there was absolutely no visible toe imprint. Total scores were calculated for the left and right feet and then analyzed as the number of toes in contact with the ground. The number of floating toes was determined from the data of contacting and non-contacting toes, and the results were analyzed.

The questionnaire asked the children's guardians about their child's developmental history, height and weight at birth, and when he/she started walking without assistance.

In the statistical analysis, Spearman's rank correlation coefficient was calculated using age in months, physique, foot morphology, and toe contact as variables. Partial correlation was also assessed using age in months, height and weight as moderator variables. Statistical analyses were performed using SPSS Statistics 20 (IBM Co., Ltd., IL, USA), and significance was accepted for values of $p < 0.05$.

RESULTS

Age in months, height, weight, and foot length and width all exhibited significant correlations ($p < 0.01$). Among the physical attributes, height had a particularly strong correlation with foot length and width. There were no significant correlations between the number of the floating toe and the height or weight of the children at the time of measurement. Only foot length significantly correlated with height and weight at birth. However, the absolute value of the correlation coefficient was 0.152, so even though it was significant, the correlation was very weak ($p < 0.05$). There were no differences by gender in all these results.

At least 1 floating toe was observed in over 87% of all children: 87.7% of the 3-year-old children (50 children), 88.7% of the 4-year-old children (55 children), and 98.7% of the 5-year-old children (78 children). The majority of children had either 0 or 1 floating toe on both the left and right foot at all ages (3-year-old: left 52.7%, right 59.7%; 4-year-old: left 62.9%, right 56.4%; 5-year-old: left 69.6%, right 60.7%) (Table 2). The most common total number of floating toes on both feet was 2, occurring in 26.3%, 24.2%, and 25.3% of the 3, 4, and 5-year-old children, respectively. The fifth toe was the most common floating toe, occurring in 74.2% of children of all ages (Table 3).

Partial correlation using age in months, height, and weight as the modulator variables revealed that only weight at birth was significantly correlated with the number of floating toes on both feet ($p < 0.05$). The absolute value of the partial correlation coefficient was 0.147, showing a very weak correlation. There were no significant correlations for the other partial correlation variables of height at birth, time of starting to walk, and foot length and width (Table 4).

DISCUSSION

There were strong correlations between foot morphology and child age in months, height, and weight, with a particularly strong correlation for height. This finding suggests that foot morphology growth is related more closely to height than to age in months and weight. Weight at birth exhibited a weak but significant correlation with floating toe. Height at birth was not related to foot morphology or floating toes.

In terms of foot contact, we found that floating toe was present in the majority of subjects and most frequently involved the fifth toe. Also in a study of 300 children aged 3 to 5 years reported in Japanese by Matsuda et al.¹⁵⁾, a high incidence of floating toe was also seen in all age groups, but the incidence of floating toe in toes other than the fifth

Table 2-1. Incidence rates of “floating toes” on one foot

	Left (%)						Right (%)					
	0	1	2	3	4	5	0	1	2	3	4	5
3Y	31.6	21.1	15.8	15.8	15.8	0.0	28.1	31.6	28.1	5.2	7.0	0.0
4Y	24.2	38.7	19.4	8.0	8.0	1.6	29.0	27.4	24.2	11.3	8.0	0.0
5Y	21.5	48.1	21.5	1.2	6.3	1.2	10.1	50.6	21.5	10.1	2.5	5.2

Table 2-2. Incidence rates of “floating toes” on both feet (%)

	0	1	2	3	4	5	6	7	8	9	10
3Y	12.3	12.3	26.3	12.3	12.3	12.3	7.0	1.8	3.5	0.0	0.0
4Y	11.3	14.5	24.2	19.4	14.5	4.8	3.2	4.8	1.6	1.6	0.0
5Y	1.3	25.3	25.3	12.7	16.5	11.4	5.1	0.0	0.0	1.3	1.3

Table 3. Percentage occurrence of “the floating toes” in each age group

		First toe	Second toe	Third toe	Fourth toe	Fifth toe
3Y	Right	0.0	8.7	17.5	38.5	66.6
	Left	0.0	22.8	28.0	43.8	68.4
4Y	Right	0.0	16.1	20.9	32.2	59.6
	Left	1.6	9.6	12.9	33.8	72.5
5Y	Right	3.7	7.5	16.4	36.7	88.6
	Left	1.2	10.1	8.8	29.1	75.9
Total (%)		2.7	13.6	17.1	36.8	74.2

Table 4. Partial correlation coefficient between the physical morphology and “the floating toe”

Evaluation item	the floating toe		
	Right	Left	Both
Foot length			
Right	-0.080	0.103	0.018
Left	-0.110	0.013	-0.061
Foot width			
Right	0.047	0.120	-0.104
Left	0.010	0.070	0.051
Height at birth	0.082	0.085	0.103
Weight at birth	0.110	0.130	0.147*
Time of starting to walk	0.009	0.036	0.028

*p<0.05

toe decreased with age according to their longitudinal observation. A decreasing number of floating toes with age was not found in the present study, which was based on a cross-sectional study design.

The present results also indicate that the number of floating toes is not related to foot morphology, height at birth, or time of starting to walk. Foot morphology strongly correlated with both age in months and height, but our present findings suggest that floating toe occurs regardless of age in months, height, foot morphology, or time of starting to walk. Weight at birth had a very weak correlation with the number of floating toes of both feet, but this tendency was not seen for the left or right foot alone, precluding a strong assertion that weight at birth affects floating toe. These findings suggest that floating toe does not occur with increased age or physical development, but is affected by other factors, such as motor development or environmental or lifestyle factors.

In terms of motor development, it has been reported that standing balance control of children aged 6 years and older undergoes a transition to become almost the same as that of adults^{16, 17}). A separate study argued that, in terms of the standing balance control of children aged 6 years and younger, inputs from the support surface and the muscles surrounding the ankles play an important role in dynamic balance control. When these inputs are inadequate, visual inputs tend to be incorrect, making balance maintenance difficult even when there is correct input to the vestibular system and motor senses other than ankles¹⁸). These findings

indicate that understanding foot contact from infancy and continuing to observe a subject throughout his/her physical and motor development are essential to help ensure proper balance control and gait. A study of plantar pressure in children aged 3.5 to 6.5 years by Matsuda and Demura¹⁹) found that, during infancy, plantar pressure on the front of the foot increases, and individual differences decrease as children get older, while Kojima and Takemori²⁰) found in a study of individuals aged 1.5 to 20 years, that pressure in the center of the foot tends to move forward with age. Taken together with the present finding that floating toe is not related to age in months or physical development, these results indicate the necessity of considering foot development from several points of view such as plantar pressure, motor development, and lifestyle factors.

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