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Relationship between Children's Toes and Kindergartens' Barefoot Policy

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Abstract

This study clarified the relationship between children's toes and kindergartens' barefoot policy by comparing the condition of untouched toes, that is, toes not touching the ground while standing normally, between children who attended kindergartens following a barefoot policy and those who did not. Participants were 552 children (299 boys and 253 girls) attending kindergartens that followed a barefoot policy and 538 children (286 boys and 252 girls) attending kindergartens that did not follow this policy. The presence of floating toes was determined from pictures of participants' soles on a contact surface area. For boys, the percentage of untouched toes was significantly lower for those who attended kindergartens following a barefoot policy (50.5%) than for those who attended kindergartens not following this policy (66.4%). Moreover, the number of untouched toes was significantly lower in children who attended kindergartens following a barefoot policy than for those who did not. On the other hand, results for boys differed from those for girls. Possibly, the occurrence of young children's untouched toes decreases when they attend kindergartens following a barefoot policy, especially for those who are very active.

Keywords

Preschool Children, Barefoot, Untouched Toes, Foot Shape, Shoe

1. Introduction

The human foot's contact sole is the only region that touches the ground when standing, walking, or running. As part of the foot, the toes play an important role in maintaining posture and locomotion when standing, walking,

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and running (Chou et al., 2009; Hughes, Clark, & Klenerman, 1990; Tanaka et al., 1996). Recently in Japan, however, reports have asserted that many children's toes do not touch the ground when they stand normally (Akamatsu & Nakatsuka, 2014; Fukuyama & Maruyama, 2011), and this condition is termed "untouched toes" (Araki, Masuda, Jinno, & Morita, 2015; Matsuda, Demura, Kasuga, & Sugiura, 2011). Reports also state that the number of children with untouched toes is increasing: currently, the percentage is over approximately 70% (Araki et al., 2015; Matsuda et al., 2011; Matsuda et al., 2009). Considering the toes' important function, untouched toes may negatively affect posture during standing, daily performance, and physical activity (Harada, 2001). Matsuda, Demura, Kasuga, and Sugiura (2013) reported that the more toes not touching the ground when standing, the greater the heel load becomes. As the foot load's anterior percentage grows from young childhood to later childhood (Matsuda & Demura, 2013; Usui, Maekawa, & Hirasawa, 1995), children with untouched toes are undesirable for normal development and growth (Matsuda et al., 2013). Another study reported a relationship between untouched toes, general malaise, and physical symptoms in adult women (Akamatsu & Nakatsuka, 2014). Considering the role of the toes and the studies mentioned above, toes that touch the ground are desirable.

Some Japanese kindergartens follow a barefoot policy. The children who attended kindergartens following a barefoot policy play barefoot indoors after arriving at their kindergarten. Although this policy positively affects formation of the medial longitudinal arch (Asami, Ishijima, & Shibukawa, 1990), few studies have examined and evidenced support of the policy's effectiveness. To evaluate it comprehensively, its effect should be examined from various viewpoints, especially in preschool children. If the policy's results become clear, this information will be useful for each kindergarten in deciding whether to adopt the barefoot policy.

As children's gait and muscle activity differ when barefoot and when wearing shoes (Franklin, Grey, Heneghan, Bowen, & Li, 2015), their foot shape changes by habitually going barefoot (Morio, Lake, Gueguen, Rao, & Baly, 2009; Rao & Joseph, 1992; Wolf et al., 2008). Additionally, as children's foot bones contain more cartilage than those of adults and because the bones' development is marked in childhood (Cheng et al., 1997), the shape of children's feet easily changes from external pressure. The toes are also expected to change according to differences of the period of being barefoot and moving barefoot. The load to the toes increases when walking (Hughes et al., 1990; Stokes, Hutton, Stott, & Lowe, 1979), and it increases more when going barefoot than when wearing shoes. The toes are freely and frequently used when barefoot. Moreover, the toes have low external pressure when barefoot, but shoes add external pressure. Thus, children who attend kindergartens following a barefoot policy are expected to have fewer untouched toes than others because they spend more time moving barefoot.

This study aims to clarify the relationship between children's toes and kindergartens' barefoot policy by comparing the condition of the toes of children attending kindergartens following a barefoot policy with those attending kindergartens that do not.

2. Methods

2.1. Participants

Participants in this study were 552 children (299 boys and 253 girls) who attended kindergartens that followed a barefoot policy (barefoot group) and 538 children (286 boys and 252 girls) who attended kindergartens that did not follow a barefoot policy (non-barefoot group). Participants in the barefoot group played barefoot indoors after arriving at their kindergartens. **Table 1** and **Table 2** show the number of participants in each age category and their physical characteristics, respectively. Years in age were divided by 12 and used as the age of each participant. Furthermore, the age category was divided into anterior and posterior halves. For example, a child whose age was from 4.0 to 4.5 was defined as a 4.0 category. Two-way analysis of variance (group × age) was conducted in age, height, and body weight, but the two groups did not differ significantly in age and height. However, body weight was significantly greater in the non-barefoot group than in the barefoot group. Because body weight is reported not to affect the occurrence ratio of untouched toes and because effect size in this study was small (boys: partial $\eta^2 = 0.01$, girls: partial $\eta^2 = 0.03$), difference in body weight was not considered in the following analysis. Age differences were found in age, height, and body weight; all variables increased with age.

2.2. Measurement of the Sole's Contact Surface Area

A pedoscope (Sakamoto, Japan) was used to record the sole's contact surface area of participants' feet and to

Table 1. Number of participants.

		4-year	4.5-year	5-year	5.5-year	6-year	6.5-year	Total
Barefoot group	Boys	61	42	50	50	60	36	299
	Girls	54	39	55	27	46	32	253
	Sum	115	81	105	77	106	68	552
Non-barefoot group	Boys	39	50	39	53	54	51	286
	Girls	34	50	51	42	38	37	252
	Sum	73	100	90	95	92	88	538

Table 2. Participants' physical characteristics and results of two-way analysis of variance (ANOVA).

				4-year	4.5-year	5-year	5.5-year	6-year	6.5-year	Total	Two-way ANOVA (group × age)			Tukey's HSD
												F	*p*	
Boys	Age	Barefoot group	Mean	4.2	4.7	5.2	5.7	6.2	6.7	5.4	Group	0.08	0.78	4 < 4.5 < 5 < 5.5 < 6 < 6.5
	(years)	(n = 299)	S.D.	0.1	0.2	0.2	0.1	0.1	0.1	0.9	Age	4065.30	0.00*	
											Interaction	0.36	0.88	
		Non-barefoot group	Mean	4.2	4.7	5.2	5.7	6.2	6.7	5.5				
		(n = 286)	S.D.	0.1	0.1	0.1	0.1	0.1	0.1	0.9				
	Height	Barefoot group	Mean	100.1	103.4	106.8	109.7	113.7	116.2	108.0	Group	2.51	0.11	4 < 4.5 < 5 < 5.5 < 6 < 6.5
	(cm)	(n = 299)	S.D.	3.5	3.7	4.2	4.0	4.6	4.0	6.9	Age	201.17	0.00*	
											Interaction	0.36	0.88	
		Non-barefoot group	Mean	99.7	103.0	106.6	108.3	112.8	116.2	108.2				
		(n = 286)	S.D.	4.0	4.1	4.7	4.2	4.7	4.0	7.0				
	Body weight	Barefoot group	Mean	16.0	16.1	17.4	17.9	20.2	20.6	18.0	Group	6.81	0.01*	Barefoot < non-barefoot
	(kg)	(n = 299)	S.D.	1.9	1.7	1.9	1.7	3.2	2.1	2.8	Age	77.43	0.00*	4 < 4.5 < 5 < 5.5 < 6 < 6.5
											Interaction	0.59	0.71	
		Non-barefoot group	Mean	16.1	17.1	18.0	18.4	20.3	21.1	18.6				
		(n = 286)	S.D.	1.6	1.8	1.8	2.0	2.4	2.4	2.7				
Girls	Age	Barefoot group	Mean	4.2	4.7	5.2	5.7	6.2	6.7	5.4	Group	3.63	0.06	4 < 4.5 < 5 < 5.5 < 6 < 6.5
	(years)	(n = 253)	S.D.	0.2	0.1	0.2	0.1	0.1	0.1	0.9	Age	3474.83	0.00*	
											Interaction	0.59	0.70	
		Non-barefoot group	Mean	4.2	4.7	5.2	5.7	6.2	6.7	5.4				
		(n = 252)	S.D.	0.1	0.1	0.1	0.1	0.1	0.1	0.8				
	Height	Barefoot group	Mean	99.0	102.9	106.2	109.9	113.4	116.0	107.1	Group	1.47	0.23	4 < 4.5 < 5 < 5.5 < 6 < 6.5
	(cm)	(n = 253)	S.D.	3.9	4.8	4.1	4.0	4.7	5.1	7.3	Age	172.96	0.00*	
											Interaction	0.90	0.48	
		Non-barefoot group	Mean	99.2	103.6	105.3	108.1	112.4	116.0	107.3				
		(n = 252)	S.D.	4.0	3.9	3.7	4.5	3.5	4.4	6.6				
	Body weight	Barefoot group	Mean	15.1	16.3	16.9	18.0	19.4	20.2	17.4	Group	14.48	0.00*	Barefoot < non-barefoot
	(kg)	(n = 253)	S.D.	1.8	2.2	2.0	1.8	2.5	2.8	2.8	Age	64.72	0.00*	4 < 4.5 < 5 < 5.5 < 6 < 6.5
											Interaction	0.67	0.65	
		Non-barefoot group	Mean	16.0	16.9	17.8	18.3	19.8	21.5	18.3				
		(n = 252)	S.D.	1.7	1.9	1.6	2.5	2.4	2.5	2.7				

Note: S.D: standard deviation, $^{*}p < 0.05$.

analyze the number of untouched toes. Participants stood barefoot on the pedoscope with their feet 5 cm apart and their hands relaxed at their sides. They were instructed to look at a mark located at eye level and to remain as still as possible during measurement. After the tester, who was a university teacher, confirmed each participant's postural stability, a picture of each sole's contact surface area was recorded. Each participant was measured sequentially five times while standing.

2.3. Judgment of Untouched Toes

Untouched-toes refer to the toes that do not show up in more than four of the five recorded pictures. Participants were defined as having untouched toes when more than one toe among those of both feet did not touch the ground. In other words, the sum of untouched toes was the total number of untouched toes on both feet.

2.4. Statistical Analysis

Independent testing was used to examine percent differences between the two groups in children with untouched toes. Two-way analysis of variance was conducted to examine differences among age categories and between the two groups in the number of untouched toes. Independent testing was used to examine differences between the two groups in the percentage of untouched toes (0 untouched toes, 1 untouched toe, over 2 untouched toes). To discover any tendency in which untouched toes appeared, occurrence rates of untouched toes for each toe were calculated. SPSS statistics 17.0 was used in these analyses, and the level of statistical significance was set at $p < 0.05$.

3. Results

Table 3 shows results of differences between the two groups in the percentage of children with untouched toes: 50.5% for the barefoot group and 66.4% for the non-barefoot group in boys—a significant difference. In girls, percentages were 54.5% for the barefoot group and 59.5% for the non-barefoot group; the difference was not significant. **Table 4** shows results of differences among age categories and between the two groups in the number of untouched toes. For boys, means for the number of untouched toes were 0.87 for the barefoot group and 1.31 for the non-barefoot group. For boys, the number of untouched toes was significantly fewer in the barefoot group than in the non-barefoot group. For girls, means for the number of untouched toes were 0.94 for the barefoot group and 1.04 for the non-barefoot group—not a significant difference between groups. **Table 5** shows results of differences between groups in the percentage of the number of untouched toes (0 untouched toes, 1 untouched toe, over 2 untouched toes). A significant difference was found for boys, and the percentage of children with more than two untouched toes was less in the barefoot group than in the non-barefoot group. There was no significant difference in the girls' percentages. **Table 6** and **Table 7** shows the number and percentage of

Table 3. Results of differences between barefoot and non-barefoot groups in the ratio of children with untouched toes.

			4-year	4.5-year	5-year	5.5-year	6-year	6.5-year	Total	χ^2 test	
										χ^2	p
Boys	Barefoot group	n	33	19	27	27	23	22	151	15.26	0.00*
	(n = 299)	Ratio (%)	54.1	45.2	54.0	54.0	38.3	61.1	50.5		
	Non-barefoot group	n	25	32	26	35	33	39	190		
	(n = 286)	Ratio (%)	64.1	64.0	66.7	66.0	61.1	76.5	66.4		
Girls	Barefoot group	n	32	25	24	15	25	17	138	1.28	0.28
	(n = 253)	Ratio (%)	59.3	64.1	43.6	55.6	54.3	53.1	54.5		
	Non-barefoot group	n	15	31	31	26	27	20	150		
	(n = 252)	Ratio (%)	44.1	62.0	60.8	61.9	71.1	54.1	59.5		

Note: *$p < 0.05$.

Table 4. Results of differences among age categories and between barefoot and non-barefoot groups in the number of untouched toes.

			4-year	4.5-year	5-year	5.5-year	6-year	6.5-year	Total	Two-way ANOVA (group × age)		
											F	*p*
Boys	Barefoot group (n = 299)	Mean	0.95	0.81	0.82	0.94	0.63	1.14	0.87	Group	19.69	0.00*
		S.D.	1.23	1.09	0.87	1.00	0.92	1.17	1.05	Age	1.04	0.39
										Interaction	0.63	0.68
	Non-barefoot group (n = 286)	Mean	1.36	1.28	1.26	1.11	1.35	1.51	1.31			
		S.D.	1.40	1.26	1.12	1.09	1.40	1.22	1.25			
Girls	Barefoot group (n = 253)	Mean	1.11	1.15	0.73	0.67	1.04	0.84	0.94	Group	0.95	0.33
		S.D.	1.21	1.06	1.01	0.68	1.17	0.88	1.06	Age	1.54	0.18
										Interaction	1.41	0.22
	Non-barefoot group (n = 252)	Mean	0.82	1.16	1.08	1.12	1.24	0.70	1.04			
		S.D.	1.31	1.17	1.06	1.17	1.10	0.74	1.11			

Note: S.D: standard deviation, $^{*}p < 0.05$.

Table 5. Results of differences between barefoot and non-barefoot groups in the ratio of the number of untouched toes.

			0 U-toe	1 U-toe	Over 2 U-toes	χ^2 test	
						χ^2	*p*
Boys	Barefoot group (n = 299)	n	148	69	82	19.0	0.00*
		Ratio (%)	49.5	23.1	27.4		
	Non-barefoot group (n = 286)	n	96	67	123		
		Ratio (%)	33.6	23.4	43.0		
Girls	Barefoot group (n = 253)	n	115	62	76	1.31	0.52
		Ratio (%)	45.5	24.5	30.0		
	Non-barefoot group (n = 252)	n	102	69	81		
		Ratio (%)	40.5	27.4	32.1		

Note: U-toe: Untouched-toe.

untouched toes for each toe. The percentage for the fifth toe was highest, and percentages for the fourth and the second toes followed.

4. Discussion

The percentages of children with untouched toes in the non-barefoot group were 66.4% for boys and 59.5% for girls. A previous study, which was conducted with 579 children aged from 3.2 to 6.2 years, reported that percentages with untouched-toes were 73.0% for boys and 69.3% for girls (Matsuda et al., 2009). In addition, Araki et al. (2015) reported that the percentage of 198 children, aged from 3 to 5 years, with more than one untouched toe was over 87%, although the measurement device and criteria for untouched toes differed in this study. Compared with previous studies, the percentage of untouched toes in this study was low. It is reported that the number of untouched toes decreases with age in childhood (Matsuda et al., 2011). As participants in this study were over 4 years old, the difference in ages of the children between this study and previous studies may affect results. Overall, however, these studies indicate that many children today have untouched toes.

The percentage of children with untouched toes was significantly less in the barefoot group (50.5%) than in the non-barefoot group (66.4%). Furthermore, the number of untouched toes was significantly fewer in the barefoot group (0.87) than in the non-barefoot group (1.31). Indeed, we clarified that children who attended kindergartens following a barefoot policy were superior in the condition of toes touching the ground. Differences in

Table 6. Number and ratio of each toe for boys with untouched toes.

The number of children with U-toe				4-year	4.5-year	5-year	5.5-year	6-year	6.5-year	Total
		B-group	n	33	19	27	27	23	22	151
		NB-group	n	25	32	26	35	33	39	190
Left foot	Fifth toe	B-group	n	23	13	21	20	17	20	114
			(%)	69.7	68.4	77.8	74.1	73.9	90.9	75.5
		NB-group	n	22	30	20	26	31	35	164
			(%)	88.0	93.8	76.9	74.3	93.9	89.7	86.3
	Fourth toe	B-group	n	4	2	0	2	2	1	11
			(%)	12.1	10.5	0.0	7.4	8.7	4.5	7.3
		NB-group	n	2	4	2	3	6	5	22
			(%)	8.0	12.5	7.7	8.6	18.2	12.8	11.6
	Third toe	B-group	n	1	0	0	0	0	0	1
			(%)	3.0	0.0	0.0	0.0	0.0	0.0	0.7
		NB-group	n	0	0	0	0	2	0	2
			(%)	0.0	0.0	0.0	0.0	6.1	0.0	1.1
	Second toe	B-group	n	3	2	2	1	1	1	10
			(%)	9.1	10.5	7.4	3.7	4.3	4.5	6.6
		NB-group	n	4	3	1	2	4	1	15
			(%)	16.0	9.4	3.8	5.7	12.1	2.6	7.9
	First toe	B-group	n	0	0	0	0	0	0	0
			(%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		NB-group	n	0	0	0	0	0	0	0
			(%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Right foot	Fifth toe	B-group	n	18	12	17	21	15	14	97
			(%)	54.5	63.2	63.0	77.8	65.2	63.6	64.2
		NB-group	n	17	20	19	20	21	25	122
			(%)	68.0	62.5	73.1	57.1	63.6	64.1	64.2
	Fourth toe	B-group	n	6	2	0	1	0	3	12
			(%)	18.2	10.5	0.0	3.7	0.0	13.6	7.9
		NB-group	n	2	2	4	3	4	6	21
			(%)	8.0	6.3	15.4	8.6	12.1	15.4	11.1
	Third toe	B-group	n	1	0	0	1	0	0	2
			(%)	3.0	0.0	0.0	3.7	0.0	0.0	1.3
		NB-group	n	1	0	0	2	0	2	5
			(%)	4.0	0.0	0.0	5.7	0.0	5.1	2.6
	Second toe	B-group	n	2	3	1	1	3	2	12
			(%)	6.1	15.8	3.7	3.7	13.0	9.1	7.9
		NB-group	n	5	4	3	3	4	3	22
			(%)	20.0	12.5	11.5	8.6	12.1	7.7	11.6
	First toe	B-group	n	0	0	0	0	0	0	0
			(%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		NB-group	n	0	1	0	0	1	0	2
			(%)	0.0	3.1	0.0	0.0	3.0	0.0	1.1

Note: U-toe: Untouched-toe, B-Group: Barefoot group, NB-group: Non-barefoot group.

Table 7. Number and ratio of each toe for girls with untouched toes.

The number of children with U-toe				4-year	4.5-year	5-year	5.5-year	6-year	6.5-year	Total
		B-group	n	32	25	24	15	25	17	138
		NB-group	n	15	31	31	26	27	20	150
Left foot	Fifth toe	B-group	n	27	15	18	9	16	13	98
			(%)	84.4	60.0	75.0	60.0	64.0	76.5	71.0
		NB-group	n	12	24	26	21	21	11	115
			(%)	80.0	77.4	83.9	80.8	77.8	55.0	76.7
	Fourth toe	B-group	n	5	2	2	0	3	0	12
			(%)	15.6	8.0	8.3	0.0	12.0	0.0	8.7
		NB-group	n	2	3	2	0	2	1	10
			(%)	13.3	9.7	6.5	0.0	7.4	5.0	6.7
	Third toe	B-group	n	1	0	0	0	0	0	1
			(%)	3.0	0.0	0.0	0.0	0.0	0.0	0.7
		NB-group	n	0	1	0	1	0	0	2
			(%)	0.0	3.2	0.0	3.8	0.0	0.0	1.3
	Second toe	B-group	n	2	1	1	0	0	0	4
			(%)	6.3	4.0	4.2	0.0	0.0	0.0	2.9
		NB-group	n	2	3	1	1	4	0	11
			(%)	13.3	9.7	3.2	3.8	14.8	0.0	7.3
	First toe	B-group	n	0	0	0	0	0	0	0
			(%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		NB-group	n	0	0	0	1	0	0	1
			(%)	0.0	0.0	0.0	3.8	0.0	0.0	0.7
Right foot	Fifth toe	B-group	n	19	20	18	9	20	14	100
			(%)	59.4	80.0	75.0	60.0	80.0	82.4	72.5
		NB-group	n	7	20	22	19	17	13	98
			(%)	46.7	64.5	71.0	73.1	63.0	65.0	65.3
	Fourth toe	B-group	n	4	4	0	0	6	0	14
			(%)	12.5	16.0	0.0	0.0	24.0	0.0	10.1
		NB-group	n	2	2	3	2	1	1	11
			(%)	13.3	6.5	9.7	7.7	3.7	5.0	7.3
	Third toe	B-group	n	0	0	0	0	1	0	1
			(%)	0.0	0.0	0.0	0.0	4.0	0.0	0.7
		NB-group	n	0	2	0	1	0	0	3
			(%)	0.0	6.5	0.0	3.8	0.0	0.0	2.0
	Second toe	B-group	n	1	2	0	0	2	0	5
			(%)	3.1	8.0	0.0	0.0	8.0	0.0	3.6
		NB-group	n	3	3	0	1	2	0	9
			(%)	20.0	9.7	0.0	3.8	7.4	0.0	6.0
	First toe	B-group	n	0	0	0	0	0	0	0
			(%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		NB-group	n	0	0	1	0	0	0	1
			(%)	0.0	0.0	3.2	0.0	0.0	0.0	0.7

Note: U-toe: Untouched-toe, B-Group: Barefoot group, NB-group: Non-barefoot group.

gait between being barefoot and wearing shoes may affect these results. Many previous studies reported that step length, cadence (step frequency), and foot pressure when contacting the ground differ when barefoot and when wearing shoes (Franklin et al., 2015; Lythgo, Wilson, & Galea, 2009; Wegener, Hunt, Vanwanseele, Burns, & Smith, 2011). Additionally, rear-foot strike at landing during running is facilitated when wearing shoes because shoes attenuate landing impact (Wegener et al., 2011). On the other hand, forefoot strike pattern at landing happens frequently when barefoot (Lieberman et al., 2010). These differences in gait and landing affect foot shape (D'Août, Pataky, De Clercq, & Aerts, 2009; Morio et al., 2009; Rao & Joseph, 1992). D'Août et al. (2009) reported that foot width is greater in habitually barefoot walkers than in habitually shoed walkers. Rao and Joseph (1992) examined the relationship between footwear and flat feet in 2300 participants aged from 4 to 13 years, reporting that people who habitually wear shoes have more flat feet than people who do not. Sachithanandam and Joseph (1995) also reported that wearing shoes beginning in childhood affects flat feet. As just described, there is a relationship between going barefoot/wearing shoes and foot shape. In addition, because a forefoot strike pattern is used (Lieberman et al., 2010) and the anterior foot load is high when barefoot (Wolf et al., 2008), load is added to the toes (Hughes et al., 1990; Stokes et al., 1979). Hasegawa et al. (2007) reported that the metatarsal-phalange joint's range of motion is greater when walking barefoot compared with walking with shoes; the toes are also utilized when barefoot. On the other hand, as shoes compress toes, at least somewhat, their mobility is limited when wearing shoes. These differences affect the toes' shape. Although the previous study was conducted with elementary schoolchildren (Enishi, Yamasaki, Hirakawa, Matsunaga, & Ono, 2008), it reported that deformation of the first and fifth toes is less for children who attended an elementary school following a barefoot policy than for children who did not. From these previous studies, it seems that the condition of toes during standing changes by increasing the amount of barefoot activity. Children who attended kindergartens following a barefoot policy spent most of the daytime barefoot, thus increasing barefoot activity time. Inferentially, differences in barefoot activity time affected differences between groups in percentages and numbers of children with untouched toes.

On the other hand, significant differences were not found in the percentage of children with untouched toes and the number of untouched toes for girls—unlike for boys. Although there are some sex differences at various points in childhood, and sex differences are not special, presuming which factors relate to these results are difficult. For example, differences in shoes for girls and boys might be a factor. However, the factor most related to this result is the amount of activity, which is lower for girls than for boys (Hinkley, Crawford, Salmon, Okely, & Hesketh, 2008). As mentioned above, foot shape differs between habitual barefoot walkers and habitually shod walkers; possibly, the greater the frequency of walking and running, the more marked the difference. If the amount of activity is low, changes in foot shape caused by differences between being barefoot or wearing shoes might not be clear.

The percentage of children with more than two untouched toes was higher in the non-barefoot group than in the barefoot group for boys (**Table 5**). Matsuda et al. (2013) reported that the more children have untouched toes, the clearer the tendency toward heel load. From this study's results, children who attend kindergartens following a barefoot policy have low potential for heel load. Because the percentage of anterior foot load grows from young childhood to later childhood, boys who attend kindergartens following a barefoot policy are considered superior in general development and growth of foot load. Possibly, marked heel load triggers unnecessary muscle activation. Women with untouched toes have tended to report more low-back pain, shoulder stiffness, and neck stiffness than women without untouched toes (Akamatsu & Nakatsuka, 2014). Thus, children who attend kindergartens following a barefoot policy might experience fewer and less intense physical disorders in the future. Relationships between untouched toes and posture, muscle activation, and a sense of malaise could be examined in a future study similar to this one.

As in previous studies (Araki et al., 2015; Matsuda et al., 2009), in this study, untouched toes occurred most in the fifth toe and, subsequently, in the fourth and second toes. We infer that a barefoot policy does not correct already untouched toes. Although we examined the barefoot policy's effect on untouched toes, its effects should be examined multilaterally. In the future, the effect of a barefoot policy on various factors other than untouched toes should also be examined.

5. Conclusion

This study examined the relationship between untouched toes and kindergartens' barefoot policy by comparing

children who attended kindergartens following a barefoot policy and those who did not. For boys, the percentage of children with untouched toes was significantly lower for those who attended kindergartens following a barefoot policy (50.5%) than for those children who did not (66.4%). Moreover, the number of untouched toes was significantly lower for children who attended kindergartens following a barefoot policy than for those who did not. On the other hand, results differed for boys and girls. Possibly, therefore, young children's untouched toes are decreased by kindergartens following a barefoot policy, especially for very active children.

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Authors' Contributions

MS controlled this study, performed the experiment, analyzed the data, and wrote the manuscript. KK cooperated with assembling the participant and conducting the measurement and helped to draft the manuscript. HT cooperated with assembling the participant and conducting the measurement. DT cooperated with assembling the participant and conducting the measurement. All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

Competing Interests

None of the authors declare competing interests.

References

Akamatsu, M., & Nakatsuka, M. (2014). General Malaise and Physical Symptoms in Young Women with Untouched Toe. *Acta Medica Okayama, 68*, 137-142.

Araki, T., Masuda, T., Jinno, T., & Morita, S. (2015). Incidence of Floating Toe and Its Association with the Physique and Foot Morphology of Japanese Children. *Journal of Physical Therapy Science, 27*, 3159-3162. http://dx.doi.org/10.1589/jpts.27.3159

Asami, T., Ishijima, S., & Shibukawa, K. (1990). The Effects of Bare Feet Life on Physical Structure, Function and Feet Sole Shape in Kindergartener. *Report of Research Center in Physical Education, 18*, 83-94. (In Japanese)

Cheng, J. C., Leung, S. S., Leung, A. K., Guo, X., Sher, A., & Mak, A. F. (1997). Change of Foot Size with Weightbearing. A Study of 2829 Children 3 to 18 Years of Age. *Clinical Orthopaedics and Related Research, 342*, 123-131. http://dx.doi.org/10.1097/00003086-199709000-00019

Chou, S. W., Cheng, H. Y., Chen, J. H., Ju, Y. Y., Lin, Y. C., & Wong, M. K. (2009). The Role of the Great Toe in Balance Performance. *Journal of Orthopaedic Research, 27*, 549-554. http://dx.doi.org/10.1002/jor.20661

D'Août, K., Pataky, T. C., De Clercq, D., & Aerts, P. (2009). The Effects of Habitual Footwear Use: Foot Shape and Function in Native Barefoot Walkers. *Footwear Science, 1*, 81-94. http://dx.doi.org/10.1080/19424280903386411

Enishi, K., Yamasaki, S., Hirakawa, K., Matsunaga, K., & Ono, N. (2008). Foot Measurement Result of Elementary School Students Spending School Life Barefoot. *Kutsuno Igaku, 22*, 42-46. (In Japanese)

Franklin, S., Grey, M. J., Heneghan, N., Bowen, L., & Li, F. X. (2015). Barefoot vs Common Footwear: A Systematic Review of the Kinematic, Kinetic and Muscle Activity Differences during Walking. *Gait Posture, 42*, 230-239. http://dx.doi.org/10.1016/j.gaitpost.2015.05.019

Fukuyama, K., & Maruyama, H. (2011). Occurrence of Floating Toe from the Viewpoint of the Structure of Foot Arch. *Journal of Physical Therapy Science, 23*, 33-36. http://dx.doi.org/10.1589/jpts.23.33

Harada, S. (2001). A Study on Physical Structures of Preschool Children's Feet Compared between 1980 and 2000. *KutsunoIgaku, 15*, 14-18. (In Japanese)

Hasegawa, M., Kanai, S., Shimizu, M. E., Shimatani, K., Tanaka, S., Oki, S., & Otsuka, A. (2007). The Influence of Footwear on the Windlass Mechanism and Toe Movement. *Structure and Function, 5*, 75-80. (In Japanese)

Hinkley, T., Crawford, D., Salmon, J., Okely, A. D., & Hesketh, K. (2008). Preschool Children and Physical Activity: A Review of Correlates. *American Journal of Preventive Medicine, 34*, 435-441. http://dx.doi.org/10.1016/j.amepre.2008.02.001

Hughes, J., Clark, P., & Klenerman, L. (1990). The Importance of the Toes in Walking. *The Journal of Bone and Joint Sur-*

gery (British Volume), 72, 245-251.

Lieberman, D. E., Venkadesan, M., Werbel, W. A., Daoud, A. I., D'Andrea, S., Davis, I. S., Mang'eni, R. O., & Pitsiladis, Y. (2010). Foot Strike Patterns and Collision Forces in Habitually Barefoot versus Shod Runners. *Nature, 463,* 531-535. http://dx.doi.org/10.1038/nature08723

Lythgo, N., Wilson, C., & Galea, M. (2009). Basic Gait and Symmetry Measures for Primary School-Aged Children and Young Adults Whilst Walking Barefoot and with Shoes. *Gait Posture, 30,* 502-506. http://dx.doi.org/10.1016/j.gaitpost.2009.07.119

Matsuda, S., & Demura, S. (2013). Age-Related, Interindividual, and Right/Left Differences in Anterior-Posterior Foot Pressure Ratio in Preschool Children. *Journal of Physiological Anthropology, 32,* 8. http://dx.doi.org/10.1186/1880-6805-32-8

Matsuda, S., Demura, S., Kasuga, K., & Sugiura, H. (2011). Changes in Floating-Toes One Year Later in Preschool Children Based on Longitudinal Data. *Japan Journal of Human Growth and Development Research [In Japanese], 51,* 19-26. http://dx.doi.org/10.5332/hatsuhatsu.2011.51_19

Matsuda, S., Demura, S., Kasuga, K., & Sugiura, H. (2013). Relationship between Untouched-Toes and Heel Load in Preschool Children. *Advances in Physical Education, 3,* 165-168. http://dx.doi.org/10.4236/ape.2013.34027

Matsuda, S., Demura, S., Miyaguchi, K., Kasuga, K., Kitabayashi, T., Aoki, H., & Yamamoto, Y. (2009). Sex, Age, and Right and Left Differences of Floating-Toe and Its Relationship with Physique in Preschool Children. *Journal of Education and Health Science [In Japanese], 54,* 198-205.

Morio, C., Lake, M. J., Gueguen, N., Rao, G., & Baly, L. (2009). The Influence of Footwear on Foot Motion during Walking and Running. *Journal of Biomechanics, 42,* 2081-2088. http://dx.doi.org/10.1016/j.jbiomech.2009.06.015

Rao, U. B., & Joseph, B. (1992). The Influence of Footwear on the Prevalence of Flat Foot. A Survey of 2300 Children. *The Journal of Bone and Joint Surgery. British Volume, 74,* 525-527.

Sachithanandam, V., & Joseph, B. (1995). The Influence of Footwear on the Prevalence of Flat Foot. A Survey of 1846 Skeletally Mature Persons. *The Journal of Bone & Joint Surgery. British Volume, 77,* 254-257.

Stokes, I. A., Hutton, W. C., Stott, J. R., & Lowe, L. W. (1979). Forces under the Hallux Valgus Foot before and after Surgery. *Clinical Orthopaedics and Related Research, 142,* 64-72.

Tanaka, T., Hashimoto, N., Nakata, M., Ito, T., Ino, S., & Ifukube, T. (1996). Analysis of Toe Pressures under the Foot while Dynamic Standing on One Foot in Healthy Subjects. *The Journal of Orthopaedic and Sports Physical Therapy, 23,* 188-193. http://dx.doi.org/10.2519/jospt.1996.23.3.188

Usui, N., Maekawa, K., & Hirasawa, Y. (1995). Development of the Upright Postural Sway of Children. *Developmental Medicine and Child Neurology, 37,* 985-996. http://dx.doi.org/10.1111/j.1469-8749.1995.tb11953.x

Wegener, C., Hunt, A. E., Vanwanseele, B., Burns, J., & Smith, R. M. (2011). Effect of Children's Shoes on Gait: A Systematic Review and Meta-Analysis. *Journal of Foot and Ankle Research, 4,* 3. http://dx.doi.org/10.1186/1757-1146-4-3

Wolf, S., Simon, J., Patikas, D., Schuster, W., Armbrust, P., & Doderlein, L. (2008). Foot Motion in Children Shoes: A Comparison of Barefoot Walking with Shod Walking in Conventional and Flexible Shoes. *Gait & Posture, 27,* 51-59. http://dx.doi.org/10.1016/j.gaitpost.2007.01.005