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The Immediate Effects of Five-Toed Shoes on Foot Structure

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ABSTRACT

The purpose of this study is to analyze the immediate effects of five toed shoes on foot structure. Subjects consisted of 26 college-aged women with pes planus. X-ray analysis of student feet were performed both barefooted and with five toed shoes. Dependent variables were hallux valgus angle, calcaneal inclination angle, 1st metatarsal declination angle, and intermetartarsal angle. Independent *t*-test was used for statistical analysis along with SAS. Overall, there were statistically significant changes of test subject's dependent variables when wearing five toed shoes. Specifically, the hallux valgus angle decreased, the calcaneal inclination angle and 1st metatarsal inclination angle increased, and intermetatasal angles both increased and decreased, shifting towards normal range. In every case the dependent variables shifted towards a more normal range while subjects wore five toed shoes. This study only examined the immediate corrective effects of five toed shoes on foot structure, but long-term studies are needed to understand the prolonged effects of five toed shoes on foot structure.

Keywords : Five-Toed Shoe, Pes Planus, Foot Deformity, X-ray

Ⅰ. Purpose

The prolonged use of footwear in modern society has resulted in almost ubiquitous foot misalignment, deformities in foot structure, and deterioration of neurovascular / motor function in the foot. Due to neural linkage(Burkett, Kohrt & Buchbinder, 1985), diminished foot proprioception can effect the entire neurological chain associated with gait, ultimately resulting in possible diminished development in the brain(Kavounoudias, Roll & Roll, 1998). Most footwear treats the foot as a single solid segment, focusing almost solely on protecting the foot from impact and maintaining stability. Unfortunately, these footwear design principles do not reflect the natural biomechanical structure and function of the foot. These problems are most pronounced with the shape of the forefoot in almost all modern footwear.

The standard "narrow toe" construction of modern shoes forces the foot into an unnatural configuration, impacting and twisting the toes, preventing individual toe articulation, and limiting the flexion of the arch(Robbins & Gouw, 1990). Furthermore, shoe design which "improves stability" by correcting for pronation / supination actually limits the natural three dimensional movement of the foot. Finally the thick padding of shoes limits another essential function of the foot, proprioception(Robbins & Gouw, 1991).

As a result, there has been a backlash against restrictive footwear, resulting in the barefoot running phenomena of today (Christoper & McDougall, 2009; Robbins & Hanna, 1987; Shakoor & Block, 2006). However, barefoot running itself might not be enough to alleviate the deleterious effects of a lifetime of abuse to the foot structure. However, since the five toed shoe was designed according to the natural contours of the human foot, wearing this shoe might help to realign the foot back into a more natural configuration. Thus, the purpose of this study is to analyze the immediate effects of five-toed shoes on foot structure.

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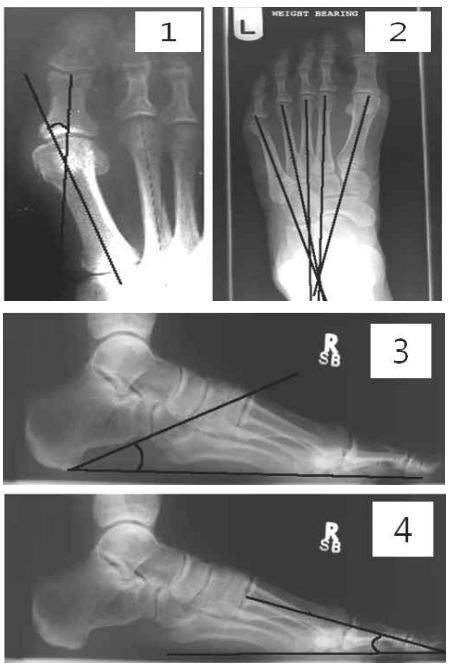
Ⅱ. Methods

The foot biomechanics of 200 female college students were measured. 70% of them had foot misalignment, specifically pes

planus and pes cavus. Among them, 26 students who had pes planus volunteered to get X-rayed to determine the exact nature of their foot misalignment.

X-Ray analysis of the sagittal and transverse planes of the foot was performed for the radiological assessment while subjects were standing both bare-footed and with five toed shoes. The independent variables were five-toed shoes and bare feet. The dependent variables were four foot-joint angles in both the right and left side: hallux valgus angle, calcaneal inclination angle, 1st metatarsal declination angle, and intermetatarsal angle <Figure 1>.



1. Hallux Valgus 2. Intermetatarsal angle
3. Calcaneal inclination angle
4. 1st Metatarsal declination angle

Figure 1. Definition of angle

Hallux abductus angle was formed by the intersection of the longitudinal axis of the first metatarsal and the longitudinal axis of the proximal phalanx of the hallux. The average angle was 15°, and a value of 20° was considered abnormal. Intermetatarsal angle was known as the metatarsus primus varus angle. It was formed by the intersection of the longitudinal axes of the first and second metatarsal shafts. The average angle was 8-10° and was an important consideration in determining the best procedure in cases of hallux valgus surgery. The average angle of the 2-3, 3-4, 4-5 intermetatarsus was 6-8° Calcaneal inclination angle was determined by connecting a point representing the most plantar aspect of the tuberosity of the calcaneus with the most distal plantar aspect of the calcaneus(at the calcaneal cuboid point).

First metatarsal declination angle was determined by the bisection the neck and the base end(not the base) of the shaft of the first metatarsal. These variables correspond to common foot deformities associated with the design of modern shoes. Both hallus valgus and intermetatarsal angle demonstrate foot deformities caused by a cramped toe box. Hallus valgus is a nearly ubiquitous foot deformity, while an intermetatarsal angle below 6-8 degrees demonstrates deformity caused by compression. Calcaneal inclination angle and 1st metatarsal declination angle demonstrate rearfoot and forefoot pronation or supination respectively.

The SAS package with a dependent t-test was used for the statistical analysis.

Ⅲ. Results

There were significant statistical changes in both the right and left foot angles (hallux valgus angle, calcaneal inclination angle, 1st metatarsal inclination angle, and intermetatarsal angle) between five-toed shoes and barefeet.

A. Hallux Valgus

Average value of hallux abductus angle wae 15-20°. Four categories

Table 1. Hallus valgus angle(left foot)

Hallux Vagus LT		*Mean*	mean diff	min	max	*t*	df	*p*
below normal(14.9°)	bare foot	11.72	(10.72)	6.58	14.10	12.96	8.00	0.00
	five-toed shoe	1.00		1.00	1.00			
Normal(bw 15-20°)	bare foot	17.07	(15.07)	15.13	19.50	33.76	8.00	0.00
	five-toed shoe	2.00		2.00	2.00			
above normal(20.1-30°)	bare foot	23.64	(20.64)	20.20	27.00	14.86	3.00	0.00
	five-toed Shoe	3.00		3.00	3.00			
Extreme(above 30.1°)	bare foot	30.83	(26.83)	24.70	37.00	7.56	2.00	0.02
	five-toed shoe	4.00		4.00				

Table 2. Hallus valgus angle(right foot)

Hallux Vagus RT		*Mean*	mean diff	min	max	*t*	df	*p*
below normal(14.9°)	bare foot	9.55	(3.47)	5.77	14.90	5.38	13.00	0.00
	five-toed shoe	6.07		1.74	12.10			
Normal(bw 15-20°)	bare foot	16.38	(5.54)	15.00	19.10	3.45	6.00	0.01
	five-toed shoe	10.84		3.80	18.70			
above normal(20.1-30°)	bare foot	22.89	(10.09)	20.67	24.30	3.33	2.00	0.08
	five-toed Shoe	12.80		9.40	19.20			
Extreme(above 30.1°)	bare foot	34.00	(14.30)	34.00	34.00			
	five-toed shoe	19.70		19.70	19.70			

were used to evaluate the angle of the Hallus Valgus: below normal(below 14.9 °), normal(15-20 °), above normal (20.1-30 °), and extreme (above 30 °). There was an overall decrease of the hallux valgus angles in both the right and left feet in all four categories. Statistically significant decreases appeared in the following groups: in the left foot, below normal(t=12.96, p<.01), normal(t=33.76, p<.01), above normal(t=14.86, p<.01), and extreme(t=7.56, p<.05), and in the right foot, below normal(t=5.38, p<.01) and normal(t=3.45, p<.01) <Table 1>, <Table 2>.

B. Calcaneal Inclination Angle

Average value of the calcaneal inclination was between 18-22 °. Calcaneal inclination angle with pronation, the angle could be decreased significantly. While calcaneal inclination angle with supination, the angle could be increased significantly. There was a statistically significant decrease in the above normal category in the right foot(t=2.75, p<.05) <Table 3>, <Table 4>.

Table 3. Calcaneal inclination angle(left foot)

Calcaneal Inclination Angle LT		*Mean*	mean diff	min	max	*t*	df	*p*
below normal (17.9°)	bare foot	16.75	1.24	12.30	17.70	(1.99)	10.00	0.07
	five-toed shoe	17.99		13.30	22.20			
Normal (bw18-22°)	bare foot	20.09	(0.48)	18.40	22.10	0.99	13.00	0.34
	five-toed shoe	19.61		17.00	23.30			

Table 4. Calcaneal inclination angle(right foot)

Calcaneal Inclination Angle RT		*Mean*	mean diff	min	max	*t*	df	*p*
below normal (17.9°)	bare foot	15.58	(0.25)	11.50	17.70	0.38	9.00	0.71
	five-toed shoe	15.33		10.70	22.40			
Normal (bw18-22°)	bare foot	19.88	(0.01)	18.60	21.70	0.01	8.00	0.99
	five-toed shoe	19.87		16.40	23.10			
above normal (22.1°)	bare foot	23.72	(2.62)	22.90	24.20	2.75	5.00	0.04
	five-toed shoe	21.10		18.10	23.70			

C. 1st Metatarsal Declination Angle

1st metatarsal declination angle demonstrate forefoot pronation or supination. There was an overall increase of the 1st metatarsal declination angles in both the right and left foot in three categories.

There was a statistically significant increase in the 1st metatarsal declination angle in only the below normal category in the right foot(t=-2.97, p<.05) <Table 5>, <Table 6>.

Table 5. 1st Metatarsal declination angle(left foot)

1st Metatarsal Inclination Angle LT		*Mean*	mean diff	min	max	*t*	df	*p*
below normal (19.9°)	bare foot	17.77	0.69	13.70	19.60	(1.49)	10.00	0.17
	five-toed shoe	18.46		15.10	20.90			
above normal (20°)	bare foot	21.68	0.74	20.10	23.56	(1.55)	13.00	0.15
	five-toed shoe	22.42		19.30	26.60			

Table 6. 1st Metatarsal declination angle(right foot)

1st Metatarsal Inclination Angle RT		*Mean*	mean diff	min	max	*t*	df	*p*
below normal (19.9°)	bare foot	17.77	0.69	13.70	19.60	(1.49)	10.00	0.17
	five-toed shoe	18.46		15.10	20.90			
above normal (20°)	bare foot	21.68	0.74	20.10	23.56	(1.55)	13.00	0.15
	five-toed shoe	22.42		19.30	26.60			

D. Intermetatarsal Angle

The average angle between the first and second metatarsal was 8-10°. Intermetatarsal angles that exceed 22° indicate that a first metatarsal medial cuneiform joint.

In the left foot, there were statistically significant increases in the angles between the 2nd and 3rd metatarsal in the below normal category(t=2.61, p<.05).

Between the 3rd and 4th metatarsal, there was a statistically significant increase in the below normal category(t=-4.37, p<.01) but a decrease in the above normal category(t=4.45, p<.05).

In the right foot, there were statistically significant increases in the angles between.

1st and 2nd metatarsal in the normal category(t=2.73, p<.05) but a decrease in the normal category(t=2.88, p<.05) <Table 7>, <Table 8>, <Table 9>, <Table 10>, <Table 11>, <Table 12>, <Table 13>, <Table 14>.

Table 7. Intermetatarsal angle(left foot 1-2)

Intermetatarsal Angle LT 1-2		*Mean*	mean diff	min	max	*t*	df	*p*
below 5.9 (5.9°)	bare foot	6.29	(14.27)	5.10	7.70	(2.57)	3.00	0.08
	five-toed shoe	7.97		6.69	8.60			
normal (bw 6-8°)	bare foot	7.77	0.73	7.30	8.00	(1.26)	2.00	0.34
	five-toed shoe	8.50		8.10	9.20			
above normal (8.1°)	bare foot	10.74	(0.55)	8.10	15.00	1.02	17.00	0.32
	five-toed shoe	10.19		6.02	15.50			

Table 8. Intermetatarsal angle(left foot 2-3)

Intermetatarsal Angle LT 2-3		*Mean*	mean diff	min	max	*t*	df	*p*
below 5.9 (5.9°)	bare foot	4.44	0.54	1.68	5.90	(2.61)	16.00	0.02
	five-toed shoe	4.98		3.37	6.50			
normal (bw 6-8°)	bare foot	6.11	(0.31)	5.20	6.50	0.75	6.00	0.48
	five-toed shoe	5.80		4.80	6.90			
above normal (8.1°)	bare foot	9.20	(4.10)	9.20	9.20			
	five-toed shoe	5.10		5.10	5.10			

Table 9. Intermetatarsal angle(left foot 3-4)

Intermetatarsal Angle LT 3-4		*Mean*	mean diff	min	max	*t*	df	*p*
below 5.9 (5.9°)	bare foot	4.72	0.94	3.10	5.93	(4.37)	11.00	0.00
	five-toed shoe	5.66		3.50	6.80			
normal (bw 6-8°)	bare foot	7.24	(0.50)	6.30	7.80	1.13	9.00	0.29
	five-toed shoe	6.74		5.20	10.40			
above normal (8.1°)	bare foot	9.80	(1.80)	9.30	10.10	4.45	2.00	0.05
	five-toed shoe	8.00		7.50	8.30			

Table 10. Intermetatarsal angle(left foot 4-5)

Intermetatarsal Angle LT 4-5		*Mean*	mean diff	min	max	*t*	df	*p*
below 5.9 (5.9°)	bare foot	4.90	2.00	4.70	5.20	(3.63)	2.00	0.07
	five-toed shoe	6.90		6.20	7.90			
normal (bw 6-8°)	bare foot	6.95	0.83	6.20	8.83	(1.36)	10.00	0.20
	five-toed shoe	7.78		4.90	10.50			
above normal (8.1°-)	bare foot	11.53	(1.47)	7.30	19.10	2.10	10.00	0.06
	five-toed shoe	10.05		4.20	15.30			

Table 11. Intermetatarsal angle(right foot 1-2)

Intermetatarsal Angle RT 1-2		*Mean*	mean diff	min	max	*t*	df	*p*
below 5.9 (5.9°)	bare foot	5.14	3.39	5.00	5.27	(2.80)	1.00	0.22
	five-toed shoe	8.53		7.45	9.60			
normal (bw 6-8°)	bare foot	6.86	1.32	6.40	7.30	(2.73)	4.00	0.05
	five-toed shoe	8.18		6.70	9.50			
above normal (8.1°)	bare foot	9.83	0.38	8.30	13.60	(0.76)	17.00	0.46
	five-toed shoe	10.22		7.10	17.40			

Table 12. Intermetatarsal angle(right foot 2-3)

Intermetatarsal Angle RT 2-3		*Mean*	mean diff	min	max	*t*	df	*p*
below 5.9 (5.9°)	bare foot	4.63	0.36	2.19	5.80	(0.98)	20.00	0.34
	five-toed shoe	4.99		2.19	10.60			
normal (bw 6-8°)	bare foot	6.43	(0.50)	6.40	6.50	0.52	2.00	0.66
	five-toed shoe	5.93		4.40	7.70			
above normal (8.1°)	bare foot	8.20	(3.00)	8.20	8.20			
	five-toed shoe	5.20		5.20	5.20			

Table 13. Intermetatarsal angle(right foot 3-4)

Intermetatarsal Angle RT 3-4		*Mean*	mean diff	min	max	*t*	df	*p*
below 5.9 (5.9°)	bare foot	4.96	0.78	4.19	5.90	(1.61)	11.00	0.13
	five-toed shoe	5.74		3.90	8.90			
normal (bw 6-8°)	bare foot	6.92	(1.87)	6.00	7.60	2.88	5.00	0.03
	five-toed shoe	5.05		3.70	7.00			
above normal (8.1°)	bare foot	8.90	(1.44)	8.10	11.70	1.98	6.00	0.10
	five-toed shoe	7.46		4.20	10.60			

Table 14. Intermetatarsal angle(right foot 4-5)

Intermetatarsal Angle RT 4-5		*Mean*	mean diff	min	max	*t*	df	*p*
below 5.9 (5.9°)	bare foot	5.25	0.82	4.65	5.90	(0.76)	2.00	0.53
	five-toed shoe	6.07		4.70	7.61			
normal (bw 6-8°)	bare foot	7.10	1.60	6.50	7.80	(1.58)	8.00	0.15
	five-toed shoe	8.70		5.40	12.80			
above normal (8.1°)	bare foot	9.82	(0.28)	8.20	12.80	0.30	12.00	0.77
	five-toed shoe	9.54		5.60	13.10			

Ⅳ. Conclusions and Suggestions

Based on these results, it is possible that five-toed shoes may immediately correct foot misalignment in regard to the hallux valgus angle, the calcaneal inclination angle, the 1st metatarsal declination angle, and the intermetatarsal angle for subjects with pes planus. This realignment occurred without causing any pain to subjects. Since five-toed shoes distribute plantar pressure evenly across the foot along the transverse plane(Yi, 2010), the toes can spread out into a more natural position. Furthermore, five toed shoes are contoured to the natural shape of a human foot, with separately formed toes. Thus the five toed shoe acts as a mild corrective brace, supporting a more natural configuration of the foot, especially the toes, and helping to keep misaligned, impacted toes separate.

This study implies that five toed shoes can have a variety of effects for correcting foot misalignment. These possible effects need to be investigated in future studies. Firstly, this study focused only on the immediate effects of five toed shoes. In addition, this study did not analyze joint linkage in the lower extremities (specifically, knee and pelvic malalignment). Lastly, this study did not include subjects with pes cavus. Thus, future studies will need to examine the prolonged effects of five toed shoes, the effects of five toed shoes on the lower extremities, and the immediate corrective effects of five toed shoes on subjects with pes cavus. After these preliminary studies are enacted, larger more expansive projects can be pursued. For example, although the foot has an enormous amount of sensory receptors, many individuals have lost full articulation of their feet, especially the toes. If foot misaligment can be corrected, can full foot(and toe) articulation be restored? What effects would this have on the brain(John Ratey & Hagerman, Eric., 2009)

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