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The Effects of Shoe Type on Ground Reaction Force

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ABSTRACT

The purpose of this study is to analyze the effects of both various shoe types and bare feet on ground reaction force while walking. Ten first-year female university students were selected. A force platform(Kistler, Germany) was used to measure ground reaction force. Six types of shoe were tested: flip flops, canvas shoes, running shoes, elevated forefoot walking shoes, elevated midfoot walking shoes, and five-toed shoes. The control group was barefooted. Only vertical passive/active ground reaction force variables were analyzed. The statistical analysis was carried out using the SAS 9.1.2 package, specifically ANOVA, and Tukey for the post hoc. The five-toed shoe had the highest maximum passive force value; while the running shoe had the lowest. The first active loading rate for running shoes was the highest; meanwhile, bare feet, the five-toed shoe, and the elevated fore foot walking shoe was the lowest. Although barefoot movement or movement in five toed shoes increases impact, it also allows for full movement of the foot. This in turn allows the foot arch to work properly, fully flexing along three arches(transverse, lateral, medial), facilitating braking force and initiating forward movement as the tendons, ligaments, and muscles of the arch flex back into shape. In contrast movement in padded shoes have a tendency to pound their feet into the ground. This pounding action can result in greater foot instability, which would account for the higher loading rates for the first active peak for padded shoes.

Keywords : Five-Toed Shoe, GRF, Proprioception.

Ⅰ. Introduction

Ordinary shoes were made to protect feet, but the typical running shoe constricts the foot in a shell of cloth, foam, and rubber, creating numerous foot problems. Specifically, running shoes inhibit the foot's normal range of motion, weakening foot muscles, tendons, and ligaments(Robbins & Waked, 1997; Robbins & Gouw, 1991), constricting blood vessels and nerves in the foot, resulting in numbness(Fauci, Anthony et al., 2008). Other negative effects include over-pronatation, and knee problems(Daniel et al., 2010; Robbins & Waked, 1997). In addition, the thick layer of padding encasing the feet in running shoes can result in a loss of proprioception(Kavounoudias, Roll & Roll, 1998), foot control(Fuzhong, Fisher, John, Harmer & Peter, 2005), and normal plantar pressure distribution(Yi, 2010). To summarize, the structure of shoes can lead to degeneration, deformity, as well as misalignment of muscles, tendons, ligaments, nerves, and vessels in the foot and lower leg.

Nowadays, new shoes have been developed for the purpose of correcting posture, increasing energy expenditure, and reducing pain and discomfort for both daily life and exercise(Yi, 2005, 2009). Most of these shoes focus on the location of the heel, for example, elevating the rear foot(as with normal running shoes), the middle foot, or the forefoot.

Unfortunately, an informal poll of local university students revealed that foot health was not a very important factor when selecting shoes. The following factors(in order of importance) were considered when selecting shoes: 1. Style(shape and color) 2. Comfort 3. Shock absorption 4. Weight 5. Durability, etc.

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These student preferences do not reflect important biomechanic principles. Good shoes should not constrict the foot but rather allow all its components(bones, muscles, tendons, ligaments, nerves, and vessels) to move both freely and correctly, allowing full engagement of the foot(Yi, 2010). Specifically, flexibility in the sole and natural movement of the foot and toes should not be compromised during exercise, making tread type and sole flexibility important factors for shoes(Yi, 2009). The principles of full foot articulation for the reduction of pain and discomfort have been embraced by top running coaches for years(Christopher & McDougall, 2009). Since foot flexibility and movement can be maximized without shoes(Shakoor & Block, 2006), these coaches advocate running barefoot on the grass to diminish running-related pain and injury(Vin, 2005). Given this principle, some shoes have actually been designed to emulate running on the grass barefoot, allowing free movement of the foot(Christoper, 2009).

The simultaneous need for foot stability and flexibility is reflected in its structure and function. The two bones of the rear foot provide stability and do not shift or flex dramatically during movement. The five bones of the midfoot also provide stability by forming three different arches. Although these bones are required to shift and flex to distribute weight and impact through the arches, much of the movement in the foot happens in 19 bones(including toes) of the forefoot. The bones of the forefoot shift, flex, and move in order to provide propulsion during walking or running.

Another critical function of the foot is proprioception. Although the foot is a complex structure with fine sensory receptors, crude shoe construction limits the natural range of motion and sensory input. The constricted, narrow forefoot of most shoes contributes to forefoot degeneration, deformity, and misalignment. Misalignment also exacerbates the problems of proprioception – for example the nerve endings for twisted toes no longer make contact with the ground, and are unable to provide critical proprioceptive information. In addition, the diminished sensory input provided by padded shoes leads to neural degeneration in the foot. Thus, misalignment and diminished sensory input combine to create a negative feedback loop(Robbins & Gouw, 1991), as padded shoe wearers pound their feet into the ground in an attempt to gain more sensory information about walking surfaces.

Different types of shoes have been made alleviate these problems by replicating movement in bare feet. The Barefoot Emulator was designed to be very lightweight, so people can't feel it. This tread of shoe has nine groves to make it more flexible than the standard running shoe. However, the shape of the barefoot emulator is similar to a standard running shoe. It does not follow the natural contours of the forefoot and still does not allow the forefoot(including the toes) to move freely. Furthermore, the standard shape and fit of the barefoot emulator still inhibits arch flexion, limiting the natural motion of the foot while walking and running. Five-Toed Shoewas developed not only to be light and flexible, but also to allow the free movement of the forefoot(Yi, 2010). Although different shoe designs emulate barefoot movement, barefoot running itself is becoming more popular and research on this topic has increased in the USA(Robbins & Hanna, 1987).

Most pain and discomfort in the foot comes from force which is applied during foot contact: heel striking, mid stance, heel off, and toe off. Depending on shoe type, there could be different ground reaction force variables(Bergmann, Kniggendorf, Graichen & Rohlmann, 1995; Burkett, Kohrt & Buchbinder, 1985; Clarke, Frederick & Cooper, 1983). But most research examined several different shoes types without a comparison to barefoot walking.

Thus, the purpose of this study is to analyze and compare the effects of both various shoe types and bare feet on ground reaction force while walking.

Ⅱ. Methods

1. The Period of Study and Subjects

Ten first-year female university students were selected as subjects based on the hypothesis that less time spent in high heels equals fewer foot deformities.

A force platform(Kistler, Germany) was used to measure ground reaction force according to shoe type. Six types of shoe were

Figure 1. six type of shoe and barefoot

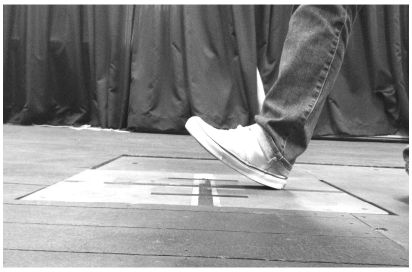

Figure 2. force platform

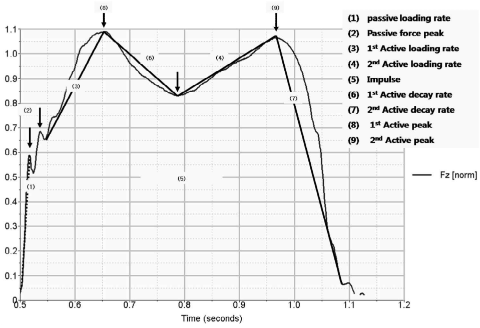

Figure 3. ground reaction variables

tested: flip flops, canvas shoes, running shoes, elevated forefoot walking shoes, elevated midfoot walking shoes, and five-toed shoes<Figure 1>. The control group was barefooted.

Dependent variables were passive force and active force(Figure 2, 3). With passive force, the variables were maximum force, maximum loading rate, and number of passive force peaks. With active force, the variables were first and second maximum force peaks, loading rates and decay rates of 1st & 2nd active peaks, and minimum trough. Only vertical ground reaction force variables were analyzed.

All subjects naturally employed a heel-strike while walking at their normal pace. The statistical analysis was carried out using the SAS 9.1.2 package, specifically ANOVA, and Tukey for the post hoc.

Ⅲ. Results

A. Passive force variables

1. Maximum Passive Force

The five-toed shoe had the highest maximum passive force value: while the running shoe had the lowest(F=6.70, p<.01, 1-7, 2-7, 3-7)(Table 1).

Table 1. Maximum Passive Force(Fz)

type of shoes	Maximum Passive Force (Fz)					F(p)	post-hoc
	N	Min(bw)	Max(bw)	Mean(bw)	SD		
barefoot(1)	10	0.48	1.19	0.76	0.23	6.70 (<0.001)	1-7, 2-7, 3-7
five-toed shoes(2)	10	0.51	1.30	0.78	0.24		
elevated fore foot walking shoes(3)	9	0.09	1.21	0.77	0.33		
elevated mid foot walking shoes(4)	9	0.10	0.94	0.53	0.28		
flip flops(5)	9	0.36	0.55	0.45	0.07		
canvas shoe(6)	6	0.09	0.88	0.41	0.26		
running shoes(7)	10	0	0.89	0.24	0.28		
Total	63	0	1.30	0.57	0.32		

2. The Highest Passive Loading Rate

The Highest Passive Loading Rate represents the Passive Force Peak divided by the time required to reach it. This represents the impact intensity. With the Highest Passive Loading Rate, the barefoot was the highest and five toed shoes were second highest; meanwhile, running shoes were the lowest(F=12.09, p<.01, 1-2, 1-6, 1-7, 2-6, 2-7)(Table 2).

3. Number of Passive Force Peaks

The Number of Passive Force Peaks represents the number of impacts occurring during a single foot strike. Bare feet and five-toed shoes had the highest N of Passive Force Peaks, but the rest of the variables had no statistically significant differences (F=56.46, p<.01, 1-3, 1-4, 1-5, 1-6, 1-7, 2-3, 2-4, 2-5, 2-6, 2-7), with less than one passive peak per foot strike(Table 3).

Table 2. The Highest Passive Loading Rate(Fz)

type of shoes	The Highest Passive Loading Rate(Fz)					F(p)	post-hoc
	N	Min(bw/sec)	max	mean	SD		
barefoot(1)	10	26.93	167.1	70.22	42.65	12.09 (<0.001)	1-2, 1-3, 1-4, 1-5, 1-6, 1-7, 2-6, 2-7
five-toed shoes(2)	10	15.20	73.93	40.95	18.86		
elevated fore foot walking shoes(3)	9	8.34	34.12	18.69	7.19		
elevated mid foot walking shoes(4)	9	5.08	25.65	11.91	6.76		
flip flops(5)	9	6.45	37.41	23.16	9.26		
canvas shoes(6)	6	3.80	24.57	12.53	7.21		
running shoes(7)	10	0	20.27	7.67	8.32		
Total	63	0	167.1	27.74	28.48		

Table 3. Number of Passive Force Peaks

type of shoes	Number of Passive Force Peaks					F(p)	post-hoc
	N	Min(bw)	Max(bw)	Mean(bw)	SD		
barefoot(1)	10	1.33	3.00	2.27	0.54	56.46 (<0.001)	1-3, 1-4, 1-5, 1-6, 1-7, 2-3, 2-4, 2-5, 2-6, 2-7
five-toed shoes(2)	10	0.33	3.33	2.03	0.74		
elevated fore foot walking shoes(3)	9	0	0.67	0.15	0.24		
elevated mid foot walking shoes(4)	9	0	0.67	0.11	0.24		
flip flops(5)	9	0	1.00	0.11	0.33		
canvas shoes(6)	6	0	0.33	0.06	0.14		
running shoes(7)	10	0	0.33	0.03	0.11		
Total	63	0	3.33	0.75	1.05		

Table 4. First Maximum Force Peak(Fz)

type of shoes	First Maximum Force Peak(Fz)					F(p)
	N	Min(bw)	Max(bw)	Mean(bw)	SD	
barefoot(1)	10	1.00	1.29	1.12	0.10	0.64 (0.700)
five-toed shoes(2)	10	0.99	1.33	1.13	0.12	
elevated fore foot walking shoes(3)	9	1.02	1.37	1.13	0.11	
elevated mid foot walking shoes(4)	9	1.00	1.34	1.12	0.11	
flip flops(5)	9	1.03	1.22	1.10	0.07	
canvas shoes(6)	6	1.01	1.15	1.06	0.05	
running shoes(7)	10	1.06	1.27	1.14	0.07	
Total	63	0.99	1.37	1.12	0.09	

B. Active Force Variables

1. First and Second Maximum Active Force Peak

First maximum active peak represents maximum active breaking force and second maximum active force shows maximum active propulsive force.

For the first and second maximum force peak, there were no statistically significant differences according to shoe type(Table 4, 5).

2. Active Loading Rate

The loading rate of active peaks signifies the intensity of active force. This rate is calculated by dividing the active peak value by time. Higher active loading rates indicate more powerful muscle contractions.

1) First Peak Active Loading Rate

The first peak loading rate for running shoes was the highest; meanwhile, bare feet, the five-toed shoe, and the elevated fore foot walking shoe was the lowest($F=3.99$, $p<.01$, 1-5, 1-6, 1-7)(Table 6).

Table 5. Second Maximum Force Peak(Fz)

type of shoes	Second Maximum Force Peak(Fz)					F(p)
	N	Min(bw)	Max(bw)	Mean(bw)	SD	
barefoot(1)	10	1.00	1.2	1.13	0.06	2.26 (0.051)
five-toed shoes(2)	10	0.99	1.22	1.13	0.07	
elevated fore foot walking shoes(3)	9	0.97	1.13	1.04	0.06	
elevated mid foot walking shoes(4)	9	1.05	1.24	1.13	0.07	
flip flops(5)	9	0.99	1.18	1.11	0.06	
canvas shoes(6)	6	1.04	1.16	1.11	0.05	
running shoes(7)	10	1.00	1.24	1.14	0.08	
Total	63	0.97	1.24	1.11	0.07	

Table 6. First Peak Active Loading Rate

type of shoes	First Peak Active Loading Rate(Fz)					F(p)	post-hoc
	N	Min(bw/msec)	Max	Mean	SD		
barefoot(1)	10	-0.30	5.37	3.45	1.54	3.99 (0.002)	1-5, 1-6, 1-7
five-toed shoes(2)	10	-2.24	5.53	3.39	2.19		
elevated fore foot walking shoes(3)	9	1.38	7.58	3.25	2.17		
elevated mid foot walking shoes(4)	9	3.25	7.35	4.87	1.36		
flip flops(5)	9	3.90	6.12	4.66	0.73		
canvas shoes(6)	6	4.04	5.13	4.68	0.41		
running shoes(7)	10	2.57	12.51	6.48	2.56		
Total	63	-2.24	12.51	4.39	2.04		

2) Second Peak Active Loading Rate

For the second peak active loading rate, there was no statistically significant difference according to shoe type. But the second peak active loading rate for running shoes, barefoot, five-toed shoe, and elevated mid foot shoe were the highest and had a similar value; meanwhile, the values for the flip flop, canvas shoe and the elevated fore foot walking shoe were the lowest(Table 7).

3) Decay Rate of the First and Second Active Peak

There were no statistically significant differences in the decay rates of the 1st & 2nd peaks.

Table 7. Second Peak Active Loading Rate

type of shoes	Second Peak Active Loading Rate					F(p)
	N	Min(bw/sec)	Max	Mean	SD	
barefoot(1)	10	-4.24	-0.79	-2.37	1.09	0.65 (0.692)
five-toed shoes(2)	10	-4.01	-0.80	-2.44	1.12	
elevated fore foot walking shoes(3)	9	-3.14	-1.23	-2.04	0.67	
elevated mid foot walking shoes(4)	9	-4.42	-0.69	-2.06	1.16	
flip flops(5)	9	-3.55	-1.42	-2.16	0.81	
canvas shoes(6)	6	-2.42	-1.00	-1.70	0.56	
running shoes(7)	10	-3.89	-1.54	-2.44	0.80	
Total	63	-4.42	-0.69	-2.21	0.92	

Table 8. Decay Rate of the First Active Peak

type of shoes	Decay Rate of the First Active Peak(Fz)					F(p)
	N	Min(bw)	Max(bw)	Mean(bw)	SD	
barefoot(1)	10	-10.93	-5.95	-8.08	1.86	1.77 (0.122)
five-toed shoes(2)	10	-11.10	-5.35	-7.90	1.83	
elevated fore foot walking shoes(3)	9	-8.48	-2.70	-6.30	1.71	
elevated mid foot walking shoe(4)	9	-10.63	-4.88	-7.99	1.66	
flip flops(5)	9	-9.51	-6.02	-7.45	1.08	
canvas shoe(6)	6	-6.88	-6.35	-6.62	0.20	
running shoes(7)	10	-10.71	-6.18	-7.95	1.64	
Total	63	-11.10	-2.70	-7.54	1.64	

Table 9. Active Loading Rate of the Second Peak

type of shoes	Active Loading Rate of the Second Peak(Fz)					F(p)
	N	Min(bw)	Max(bw)	Mean(bw)	SD	
barefoot(1)	10	0.90	3.65	2.42	1.00	2.09 (0.069)
five-toed shoes(2)	10	0.75	3.63	2.27	1.07	
elevated fore foot walking shoes(3)	9	0.53	2.13	1.32	0.54	
elevated mid foot walking shoes(4)	9	0.72	4.23	2.43	1.13	
flip flops(5)	9	1.00	3.04	1.88	0.75	
canvas shoes(6)	6	1.06	2.23	1.41	0.43	
running shoes(7)	10	0.74	4.03	2.21	1.13	
Total	63	0.53	4.23	2.03	0.98	

Table 10. Integral

type of shoes	Integral					F(p)
	N	Min	Max	Mean	SD	
barefoot(1)	10	0.48	0.72	0.62	0.07	1.98 (0.084)
five-toed shoe(2)	10	0.47	0.74	0.64	0.08	
elevated fore foot walking shoes(3)	9	0.62	0.79	0.69	0.06	
elevated mid foot walking shoes(4)	9	0.61	0.82	0.69	0.07	
flip flops(5)	9	0.62	0.75	0.67	0.05	
canvas shoes(6)	6	0.68	0.75	0.71	0.03	
running shoes(7)	10	0.54	0.78	0.68	0.07	
Total	63	0.47	0.82	0.67	0.07	

4) Integral

Integral refers to the total active forces during walking. There were no statistically significant differences in the integral.

But bare feet and five-toed shoes had the lowest value(0.40, 0.39, respectively), and elevated forefoot walking shoes and canvas shoes had the highest value(Table 10).

Table 11. Stance Time

type of shoes	Stance Time(Fz)					F(p)
	N	Min	Max	Mean	SD	
barefoot(1)	10	0.40	0.58	0.50	0.05	2.22 (0.054)
five-toed shoes(2)	10	0.39	0.60	0.52	0.06	
elevated fore foot walking shoes(3)	9	0.51	0.66	0.57	0.05	
elevated mid foot walking shoes(4)	9	0.49	0.66	0.56	0.06	
flip flops(5)	9	0.49	0.61	0.53	0.04	
canvas shoes(6)	6	0.52	0.61	0.56	0.03	
running shoes(7)	10	0.45	0.58	0.52	0.04	
Total	63	0.39	0.66	0.53	0.05	

5) Stance Time

Stance time is the duration of single leg support while walking. There were no statistically significant differences in stance time according to shoe type. But the barefoot and five-toed shoes had the overall shortest stance time and canvas shoes were the longest (Table 11).

Ⅳ. Conclusion and Suggestions

In conclusion, although biomechanists / exercise physiologists have always advocated reducing impact during any movement, these results make a contrary allusion to a relationship between passive force variables and biomechanically efficient movement. Although barefoot movement or movement in five toed shoes increases impact, it also allows for full movement of the foot. This in turn allows the foot arch to work properly, fully flexing along three arches(transverse, lateral, medial), facilitating braking force and initiating forward movement as the tendons, ligaments, and muscles of the arch flex back into shape(Robbins, Gouw & Hanna, 1989; Robbins & Hanna, 1987).

In contrast movement in padded shoes proves to be biomechanically inefficient. Although the foot is a critical sensory receptor(Kavounoudias, Roll & Roll, 1998) for locomotion, the ubiquitous use of shoes limits sensory input for the feet. As a result, people in padded shoes have a tendency to pound their feet into the ground in order to attain the fundamental sensory information for movement. This pounding action can result in greater foot instability, which would account for the higher loading rates for the first active peak for padded shoes. Furthermore, since this padding both absorbs impact force, as well as limits the natural range of motion of the foot, flexion in the arch is hindered, requiring muscles to contract in order to create breaking force. This dynamic might also be reflected in the higher values for the loading rate in the first active peak.

Since padded shoe wearers cannot flex their arch, the method of locomotion must be different. It is likely that padded shoe wearers must engage more of their muscles in their lower extremities in order to move. Possible consequences include inefficient movement, and foot atrophy(neurovascular degeneration), despite possible hypertrophic benefits in the legs.

Given the potential importance of passive force(impact) in walking efficiency, it is important to reconsider the traditional assumption that any impact forces are negative. It is possible that a limited amount of impact force(under twice body weight) can help improve strength, flexibility and bone mineral density(Yi, 2002). Further studies are needed to gain further insight into the potential positive consequences of impact, as well as the impact threshold for the human body.

Finally, although barefoot movement and five toed shoes provide a full-range of motion and do not restrict the toes, the impact forces of the five-toed shoe might cause difficulty for those who are unaccustomed to barefoot walking(Robbins & Gouw, 1990; Robbins & Gouw, 1991; Robbins, Gouw, McClaran & Waked, 1993). So, for people who regularly walk with shoes on solid, even surfaces, an impact absorbing mechanism on the heel might be needed to compensate for this problem. However, this deficiency could be mitigated by having an adjustment period with the five-toed shoes in which they are worn on soft and uneven surfaces(such as wood and trails).

This study focused only on effects vertical force according to shoe type; however a more comprehensive analysis would provide a more complete picture on the effect of shoe type on gait. Future studies should include both medial / lateral and anterior / posterior forces exerted when walking. Pressure distribution analysis would also provide a more precise analysis of the effects of shoe type on gait, while EMG studies would clarify the differences in muscle activation between barefoot walkers and padded shoe wearers.

Reference

Bergmann, G., Kniggendorf, H., Graichen., & Rohlmann, A.(1995). Influence of shoes and heel strike on the loading of the hip joint. *Journal of Biomechanics*, 28, 817-827.

Burkett, L. N., Kohrt, M., & Buchbinder, R.(1985). Effects of shoes and foot or thotics on VO2 and selected frontal plane kinematics. *Medicine and Science in Sports and Exercise,* 17, 158-163.

Christoper., & McDougall.(2009). *Born to Run, Random House.* Inc., New York.

Clarke, T. E., Frederick, E. C., & Cooper, L. B.(1983). Effects of shoe cushioning upon ground reaction forces in running. *International Journal of Sports Medicine,* 4, 247-251.

Daniel, E., Lieberman, M. V., William, A. W., Adam, I. D., Susan, D., Irene, S. D., Robert, O. M., & Yannis, P. (2010). Foot strike patterns and collision forces in habitually barefoot versus shod runners, *Nature,* 463, 531-535.

Fauci, Anthony S., et al.(2008). *Harrison's Principles of Internal Medicine.* 17thed. United States: Mc Graw-Hill Professional.

Fuzhong, L., Fisher, J., & Harmer, P.(2005) "Improving Physical Function and Blood Pressure in Older Adults Through Cobblestone Mat Walking: A Randomized Trial," *Journal of the American Geriatrics Society,* 53(8), 1305-1312.

Kavounoudias, A., Roll, R., & Roll, J. P.(1998). "The plantar sole is a 'dynamometric map' for human balance control," Laboratoire de Neurobiologie Humaine, UMR 6562, CNRS-University de Provence, Marseille, France. *Neuro Report,* 9(14), 3247-3252.

Yi, K. O., & Lee, Y. S.(2002). The differing Effects of sports Training and Dietary Habits on the Menstrual cycle, Body composition and Bone mineral Density, in elite Korean Female Athletes. *Korean Alliance for Health, Physical Education, and Dance,* 41(4), 12-24.

Yi, K. O.(2005). The Effects of Elevated Forefoot Walking Shoes on Body Composition, Physical Fitness, and Qualitative Health Variables. *Korean Alliance for Health, Physical Education, and Dance,* 19(1), 9-26.

Yi, K. O., & Kwon, B.(2006). Difference in Pressure Distribution According to Shoe Type. *Korean Physical Education Association for Girls and Women,* 20(4), 161-168.

Yi, K. O.(2008). Immediate Differences in Gait Strategies According to Rocker Sole Configurations. *Korean Physical Education Association for Girls and Women,* 22(4), 1-13.

Yi, K. O.(2009). Mechanical Calory Expenditure Map based on the Effects of Shoe and Road. *Korean Physical Education Association for Girls and Women,* 23(3), 23-38.

Yi, K. O.(2009). The Effects of the Five-toed Shoe on Foot Pressure Distribution. *Korean Physical Education Association for Girls and Women,* 23(4), 35-44.

Yi, K. O.(2010). *The Effect of Shoe Type on Plantar Pressure Distributions.* 2010 NACK; Northeast Asia Conferenceon Kinesiology. KACEP 11th Annual Meeting. Seoul. Korea.

Robbins, S. E., & Hanna, A. M.(1987). Running-related injury prevention through barefoot adaptations. *Medicine and Science in Sports and Exercise,* 19, 148-156.

Robbins, S. E., & Gouw, G. J.(1990). Athletic footwear and chronic overloading: a brief review. *Sports Medicine*, 9, 76-85.

Robbins, S. E., & Gouw, G. J.(1991). Athletic footwear: unsafe due to perceptual illusions. *Medicine and Science in Sports and Exercise,* 23, 217-224.

Robbins, S., Gouw, G., McClaran, J., & Waked, E.(1993). Protective sensation of the plantar aspect of the foot. *Foot and Ankle,* 14, 347-352.

Robbins, S., & Waked, E.(1997). Hazards of deceptive advertising of athletic footwear. *British Journal of Sports Medicine,* 31, 299-303.

Robbins, S. E., Gouw, G. J., & Hanna, A. M.(1989). Running-related injury prevention through innate impact-moderating behavior. *Medicine and Science in Sports and Exercise,* 21, 130-139.

Shakoor, N., & Block, J.(2006). "Going Barefoot Decreases Loads on Lower Extremity Joints in Osteoarthritis," Arthritis Today Magazine. *Rheumatic Diseases,* 54, 2923-2927.