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EFFECTS OF WEARING ATHLETIC SHOES, FIVE-TOED SHOES, AND STANDING BAREFOOT ON BALANCE PERFORMANCE IN YOUNG ADULTS

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ABSTRACT

Background/Purpose: Almost all research using participants wearing barefoot-style shoes study elite runners or have participants with a history of barefoot style shoe training run on a treadmill when shod or barefoot. Wearing barefoot-style shoes is suggested as a method of transition between shod and barefoot running. Static and dynamic balance exercises also are recommended. However, little information is available on the effects five-toed barefoot style shoes have on static balance. The purpose of this study was to examine balance of subjects barefoot, wearing Vibram FiveFingers™ barefoot-style shoes, and regular athletic shoes with eyes closed when using the Biodex Balance System-SD™.

Study Design: This was a repeated measures study.

Methods: Forty nine participants aged 18-30 years without lower extremity injury or experience wearing barefoot-style shoes were tested for static balance on the Biodex Stability System™ with their eyes closed while wearing Vibram FiveFingers™, athletic shoes, or barefoot. Three trials of 10 seconds for each footwear type were completed. Repeated measures analysis of variance with Bonferroni's correction was used to analyze the degrees of sway in the anterior-posterior and medial lateral directions. An overall stability index was also calculated by the Biodex.

Results: For anterior-posterior and overall indices, differences were found between all conditions. Participants wearing athletic shoes demonstrated the smallest anterior-posterior stability index (least sway) and spent the most time in the innermost concentric circular zone. Medial-lateral indices were not different for any condition.

Conclusions: Wearing Vibram FiveFingers™ provided better overall and anterior-posterior static balance than going barefoot. While differences between Vibram FiveFingers™ and barefoot are significant, results may reflect statistical significance rather than any clinical difference in young, uninjured individuals.

Clinical relevance: It would appear that Vibram FiveFingers™ mimic going barefoot and may be a bridge for exercising in preparation for barefoot exercise.

Level of Evidence: 3B

Keywords: static balance, Biodex, postural control, postural index, Vibram FiveFingers

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INTRODUCTION

Vibram FiveFingers (VFFs), a type of barefoot footwear, is considered as a bridge from running in shoes to running barefoot.[1] Running barefoot is not without its difficulties. Rothschild recommends a preparatory program done barefoot that includes lower extremity proprioception, ankle flexibility, and intrinsic foot strengthening exercises.[2] It might be appropriate, as well, for the person wishing to run barefoot to perform these exercises wearing a barefoot shoe, especially if this person is using VFFs as a bridge to barefoot running.

Vibram FiveFingers (Albizzate, Italy) have less structure and cushioning than even minimalist shoes, defined as shoes with heel material equal in thickness slightly thicker than forefoot material with minimal or no support materials in heel or arch area.[1] Vibram's website describes them as a 5- toed lightweight and flexible shoe, without cushioning and arch support. Each toe has a separate slot. This footwear is purported to mimic the barefoot experience while providing protection for the foot.[3]

If VFFs mimic barefoot conditions, balance test results for users wearing VFFs should be similar to results obtained when they are barefoot (BF). Most studies compare kinematic, joint loading rates and muscle activity patterns in injury-free recreating or competitive adult runners in BF and shod conditions.[4] Few studies compare subjects' static or dynamic balance while barefoot and wearing VFFs. Amateur runners wearing VFFs and BF had similar static and dynamic ankle position sense when asked to estimate the perceived direction and amplitude of a support-slope surface board.[5] Dodson et al examined participants of different ages and abilities who wore VFFs for at least one hour daily for eight weeks. Star Excursion Balance and timed balance scores improved after eight weeks.[6] Tests of dynamic balance demonstrated that subjects in hard-soled shoes performed better than those who were BF.[7,8] Young adults demonstrated that performing the dynamic balance activity of walking on a balance beam[7] and during unexpected gait termination in hard-soled shoes resulted in better test scores than BF. [8] In healthy young adults, only the medial-lateral stability index was significantly smaller for BF than wearing VFFs during static balance measured on a force plate immediately after single leg jump landings.[9] Perry et al found that as midsole hardness increased, medial-lateral stability decreased as compared to a BF condition.[8]

No studies have measured static balance in subjects wearing VFFs or going barefoot using a formal testing system. Thus, the aim of this study was to assess static standing balance of subjects barefoot, wearing VFFs, and regular athletic shoes with eyes closed when using the Biodex® Balance System (BSS-SD). It was hypothesized that static balance measurements would be the same when subjects were BF or wore VFFs compared to when subjects wore regular athletic shoes.

METHODS

A single group repeated measures design was used. Each participant had their balance tested under three conditions: (1) while barefoot, (2) wearing VFFs and (3) wearing regular athletic shoes. The order of testing conditions was randomly determined.

Participants

Forty-nine volunteers aged 18-30 (males = 16; females = 33) without lower extremity musculoskeletal or neurological impairment in the last six months and no previous experience wearing BF style shoes participated. All provided informed consent prior to participation per university Institutional Review Board guidelines. Participants brought their own athletic shoes to the lab. Athletic shoes were defined as a lace-up, buckled, or Velcro-fastened shoe or canvas sneaker with a relatively wide rubber sole, fabric upper material, and a low heel height that is used for casual or athletic activities.[10] Participants refrained from exercise 24 hours prior to testing to prevent effects of fatigue. All participants wore the same model of Vibram FiveFingers® shoe (KSO). Participants were measured for size using the fit guide on the Vibram web site.[3] Participants were only allowed to move their feet within the VFFs to make sure that all the toes were in the correct place.

Balance testing

The Biodex Balance System (BSS-SD)(Biodex Medical Systems, Shirley, New York, USA) circular platform acted as a standard force plate to measure static conditions. Results are reported as the center of gravity's

angular displacement as defined by the manufacturer. Using these data, the BSS-SD software calculated indices for anterior-posterior (AP), medial-lateral (ML), and overall (OA) stability. Also measured was the percentage of time spent in one of four concentric zones around the platform's center. Each participant's feet were placed in a predetermined position (calculated by BSS-SD based on participant's height) and a familiarization session was completed.[11]

After donning the initially assigned footwear, participants were repositioned, crossed their arms over the chest and closed their eyes for each ten-second trial. Between each of the three trials for each type of footwear, participants could relax and open their eyes but not move their feet. Participants repeated the protocol with the two other footwear types in the assigned order. Trial results were discarded if the participants moved hands off the chest, moved the feet from the starting position, fell, or opened their eyes.

Statistical Analysis

Using all 9 trials for each subject, a repeated measures analysis of variance including *post hoc* analysis with Bonferroni's correction was used to compare balance scores wearing VFFs, athletic shoes, and barefoot. The data met the assumption for homogeneity of variance. The alpha level was set at 0.05; SPSS V-19 was used to analyze the data.

RESULTS

Sixteen men participated: mean age 27.2 (+/-5.6 years), mean height 179.6 (=/-4.5 cm), mean body mass 75.6 (+/- 9.9 kg). Female participants numbered 33: mean age 26.1 (+/-5.9 years), mean height 167.4 (+/-6.3 cm), mean body mass 64.0 (+/- 7.6 kg). No participant data were excluded. Overall stability indices were smallest when participants wore their regular athletic shoes (overall, 3.4˚, shoes; 5.62˚, VFF; 6.13˚, BF). Table 1 shows that anterior-posterior sway indices were similar to overall index scores. As indicated by the smaller sway, VFFs provided better stability for these two indices than BF. No differences were found for ML stability under any footwear condition (Table 1). Table 2 shows that, when participants wore athletic shoes, they spent the most time in the innermost concentric circular zone (0-5 degrees from center). Shod participants spent 76.1% of the time in the innermost zone; VFF, 39.7%; BF, 38.8%. Shod participants spent 23.5% of the time in the 6-10 degree zone; VFF 53.1%; BF, 47.9%. Along with sway indices; the percent of time spent in the 0-5 degree zone indicates better postural stability.

DISCUSSION

While VFF and BF overall and AP stability indices were statistically different, the results confirmed the hypothesis that static balance in VFFs would be similar to barefoot. In both indices, differences between VFF and BF measurements were less than 0.5 degrees. This evidence suggests that VFFs could be worn during the non-running part of a training program for those wishing to transition from running shod to running in bare feet. Experts recommend at least 4-8 weeks of transition training.[2] The program should include non-running and running

Table 1. *Static Overall stability index, Anterior/Posterior stability index, and Medial/Lateral stability index in degrees for three footwear conditions.*

Static balance index	Shoes	VFF	Barefoot
Overall Stability (mean +/- SD)	3.4(2.0) [a, b]	5.62(2.88)[a,,c]	6.13(3.39)[b, c]
Anterior/Posterior Stability (mean +/- SD)	3.13(2.08)[a,b]	5.51(2.96)[a,c]	5.98(3.51)[b,c]
Medial/Lateral Stability (mean +/- SD)	0.82(0.82)	0.63(0.50)	0.70(0.65)

[a] Significantly different $p \leq .05$, shoes vs. VFF
[b] Significantly different $p \leq .05$, shoes vs. barefoot
c significantly different $p \leq .05$, VFF vs. barefoot

Table 2. *Percentage of time spent in the four zones with subjects in three footwear conditions (does not add to 100% due to rounding).*

Zone	Shoes	VFF	Barefoot
A (0-5 degrees from center)	76.1 (33.9)[a, b]	39.7 (42.6)[a]	38.8(44.6)[b]
B (6-10 degrees from center)	23.5 (33.3)[a]	53.1(39.2)[a]	47.9 (42.1)
C (11-15 degrees from center)	0.4 (1.9)[a,b]	6.9 (16.4)[a,c]	12.7 (27.5)[b,c]
D (16-20 degrees from center)	0.0	0.4 (2.4)	0.5 (2.6)

All values are mean +/- standard deviation
[a] shoes significantly different from VFF $p \leq 0.05$
[b] shoes significantly different from barefoot ≤ 0.05
[c] VFF significantly different from barefoot $p \leq 0.05$

activities. Lower extremity proprioception exercises should include ankle range of motion on fixed and dynamic surfaces and single leg stance activities. Kelly etal found that activation of plantar intrinsic foot muscles increased when barefoot participants balanced in one leg stance as compared to double limb stance.[12] Wearing athletic shoes provided the best OA and AP static balance. These differences were also reflected in the greater amount of time spent in the 0-5° concentric circle immediately around the platform's center. Literature supporting athletic shoe wear as safer than BF during walking comes from studies of subjects older than 60 years. Koepsell et al found that older adults wearing athletic shoes had the lowest risk of falls.[13] Older adult women performed better when wearing low-heeled shoes. [14] However, Tencer et al found that shoe sole thickness and stiffness had little relation to fall risk in older adults.[15]

Hosada et al studied 18-22 year old subjects and concluded that thicker soles may inhibit sending of information from receptors from the sole and the ankle joints as well as from muscle spindles in ankle joint muscles, resulting in reduced reaction speed and strength.[16] Perry et al studied young females and concluded that wearing soft mid-soled footwear decreased their ability to respond to imposed perturbations.[8] Menant and Perry et al compared young and old adults in various shod conditions. They reported that soft insoles led to poor balance because they offered less mechanical support, which may be detrimental to joint position sense, especially in the elderly.[17] Balance failures while walking on a balance beam occurred least when subjects wore thin hard-sole shoes: significantly fewer than BF or any other combination of sole thickness and hardness.[7] The contrast in results between this and previous research may stem from the small amounts of postural disturbance measured by the BSS-SD With regard to time spent in zones, these findings support the literature that normal individuals remain near the center platform position during static balance.[18,19] However, the force plate recordings of the ground reaction force and the electromyographic assessment used by Tropp and Odenrick were very different from the methods used in the current study.[18] Arnold and Schmitz studied only single limb stance using the BSS-SD.[19]

Proprioception from different areas of the foot may play a role in balance reactions when wearing VFFs. Four static postural control variables were studied in physically active adults wearing a five-toed sock, a regular sock, and BF in single leg stance. The authors hypothesized that wearing a five-toed sock would improve balance because of the novel tactile sensation between the toes. No significant differences were found in any variables for any condition.[20] Researchers who study results comparing VFFs, BF or to the shod condition argue that each of these conditions provides different information from around the toes and from the sole. Most published results in which participants wear VFFs evaluate measurements are taken from the sole while running. Paquette et al and McCarthy et al found that VFFs provided the greatest ankle range of motion, especially in plantarflexion, compared to BF or shod.[21,22] Compared to standard shod condition, energy consumption during running and peak impact force were significantly lower with VFFs. Lower limb kinematics with VFF were similar to BF running.[23] VFFs provided a better perception of ankle range of motion while standing and running compared to BF.[5]

This study is not without limitations. Only volunteers without ankle or foot injury participated. Test-

ing results of individuals with acute ankle injuries, those prone to chronic ankle instability, or those with other lower extremity orthopedic conditions may differ from current findings. Assessing static postural control may not be the most possible relevant measure of the effectiveness of VFFs. Balance measurements taken while participants perform recommended exercises[2] would provide information about dynamic balance. With VFFs, each toe is individually wrapped potentially increasing proprioceptive and cutaneous information by augmenting tactile sensations and providing pressure to the skin between the toes. Enhancing appropriate proprioceptive input from between the toes may not be possible because an even fit around each toe in VFFs unlikely. However, none of the participants in the current study had experienced wearing VFFs and this novel sensation may have interrupted the participants' concentration. Providing the same style of athletic shoe was not an option, and no effort was made to characterize the type of athletic shoes worn by participants. A general definition taken from the literature was used,[10] but no formal assessment was done such as the one developed by Menz and Sherrington.[24]

CONCLUSIONS

Wearing VFFs provided better OA and AP static balance than going barefoot. No differences were found for ML lateral stability. While differences between VFF and BF are significant, results may reflect statistical significance rather than any clinical difference in young, uninjured individuals. It would appear that VFFs mimic going barefoot and may be a bridge for exercising in preparation for non-running barefoot exercise as part of a clinician-directed exercise program or as self-preparation for barefoot running.

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