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Young Adults Performance of Unipedal Dynamic Balance with Various Footwear Conditions

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ABSTRACT

International Journal of Exercise Science 13(4): 206-215, 2020. Wearing barefoot-style (minimalist) shoes is suggested as a transition between wearing shoes and barefoot running. Some sources equate wearing Vibram FiveFingers™(VFFs), a brand of barefoot shoes, with running/walking barefoot. Static and dynamic balance exercises are recommended. Little information is available on the effects barefoot shoes may have on dynamic balance. This study's purpose was to examine dynamic balance when participants wore VFFs, athletic shoes, or went barefoot (BF). To test dynamic balance, participants used a modified version of the Star Excursion Balance Test (SEBT), in which the reaching leg followed only three spokes of the test: the anterior, posteromedial and posterolateral. For the timed test, participants touched down as quickly as possible in both directions using all 8 spokes. Thirty participants (ages 24.1+/-3.71 years) without lower extremity injury or experience wearing minimalist shoes were tested using the modified SEBT and a timed test wearing VFFs™, athletic shoes, or BF. Three trials for each footwear were completed for three reaching positions: anterior, posterolateral, posteromedial. The timed test measured (seconds) one counterclockwise and one clockwise direction of the 8-spoke figure. A repeated measures analysis of variance determined if any differences existed between footwear type and studied variables. Anterior reach was significantly greater when wearing shoes than with VFF or BF. Posteromedial reach was greater with shoes than BF. Time trials were not significantly different. Because no difference was found in any measured variables between VFF and BF, the results suggest wearing VFFS™ provided similar dynamic balance as going barefoot.

KEY WORDS: Vibram FiveFingers, dynamic balance, Star Excursion Balance Test

INTRODUCTION

Over the past 10 years, running barefoot has again come to the attention of the running public. Christopher McDougall published *Born to Run* in 2009. The author compared performance of today's premier runners to current-day tribes in Africa and Mexico who run barefoot or in sandals (17). One offshoot of the popularity of barefoot running is the development of "minimalist" style shoes, such as Vibram FiveFingers (VFFs), and New Balance's Minimus line. One business source considers VFFs to be "barefoot" shoes" and New Balance's Minimus shoes to be "minimalist" (4). Another source considers VFFs a bridge from running in shoes to running barefoot (6).

Academic sources are also found that compare aspects of running (e.g. kinematics, economy, types of injuries) with type of shoe: conventional, minimalist or barefoot shoe, or barefoot. Study results are as variable as the methods. In 2015, Esculier etal published the Minimalist Index Rating scale and its accompanying instruction guide. Minimalist shoes are characterized by high flexibility, low weight, little or no motion control, little or no cushioning, wide toe-box, reduced height difference between the rearfoot and forefoot and limited stack height (9). Some studies that compare wearing shoes to barefoot/minimalist use the guide developed by Esculier etal (Minimalist Index Rating Scale). One study that examined the effects of minimalist shoes on foot volume used this scale and determined that VFF achieved a total index score of 92/100%. The authors considered this "a good degree of minimalism" (5). Another study used the index to determine that the shoes used in their study scored 72% on this index (10).

Multiple sources note that running barefoot is not without its difficulties. For example, Rothschild recommends a preparatory program done barefoot, which includes exercises for lower extremity proprioception, ankle flexibility, and intrinsic foot strengthening (24). Injury prevention exercises are suggested for minimal footwear transition in a systematic review of publications dealing with transition to minimal footwear (31). Individuals wishing to run barefoot may benefit from using a barefoot shoe as a transition, not only for running/walking but also using to perform strengthening and range of motion exercises for the foot and lower extremity. Others may prefer to always wear a barefoot style shoe to prevent injuries or bruising or to protect the foot during inclement weather.

Vibram FiveFingers are purported to mimic the barefoot experience while providing protection for the foot (30). If VFFs mimic barefoot conditions, balance test results for subjects wearing VFFs should be similar to results when they are barefoot (BF). Most studies compare kinematic data, joint loading rates and muscle activity patterns in injury-free recreating or competitive adult runners in BF and shod conditions (3, 11, 29). The results of these studies are equivocal.

Few studies compare subjects' static or dynamic balance while barefoot and wearing VFFs. Dodson et al examined participants of various ages and abilities who wore VFFs for at least one hour daily for 8 weeks. Undefined balance test scores improved after 8 weeks (8). Amateur runners shod in running shoes, VFFs and going BF had the most angle error in determining static ankle range of motion when wearing running shoes. When running on a treadmill, subjects who wore VFFs estimated treadmill surface slope significantly better than those who wore shoes (28).

In healthy, young adults, Rose et al reported that their force plate study showed the medial-lateral stability index was significantly smaller for BF than wearing VFFs immediately after single leg jump landings (23). Smith et al tested static balance on the Biodex Stability System™ when similar subjects had their eyes closed while wearing VFFs, athletic shoes, or BF. When participants wore athletic shoes, their anterior-posterior stability index (least sway) was

smallest and they spent the most time in the innermost concentric circular zone (another indicator of good balance). Medial-lateral indices did not change with footwear (26).

The modified SEBT (Star Excursion Balance Test) was developed from the SEBT by Plisky et al (20). Called the Y Balance Test (YBT®), it uses only 3 directions (anterior, posterolateral, posteromedial) instead of eight used in the conventional SEBT to measure single limb stance as an assessment of dynamic balance. Coughlan et al (7) compared the reach performance between the SEBT and the instrumented YBT in 20 healthy, young males. Reaches showed good agreement between SEBT and the YBT. Only in reaching in the anterior direction did the subjects reach farther using the SEBT than using the YBT.

Hart and Rothermich published a description of their variation of the Y balance test. A tape measure was affixed to the floor in a straight line with 2 pieces of tape angled at 135 degrees to create a "Y" shape on the floor (12). Hutt and Redding measured the effects of an intervention with ballet dancers as subjects and used a similar taped version of the SEBT, with 8 spokes (15).

For this report, the taped version of the YBT was used with the anterior, posteromedial and posterolateral positions clearly outlined. These were part of the 8-spoke grid used for the timed test (Figure 1).

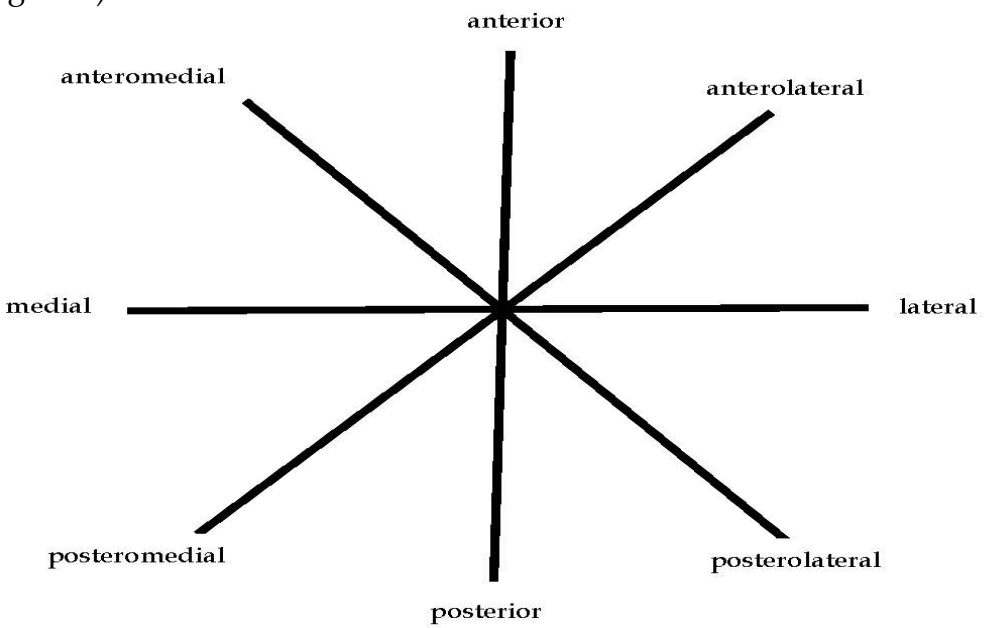

Figure 1. Eight spoke Star Excursion Balance Test (SEBT) "clock" used for timed test. Anterior, posteromedial and posterolateral positions were used for the modified SEBT.

The timed test used the original 8-spoke grid of the SEBT (15). This test was performed as quickly and safely as possible. Participants reached as far as possible in the fastest time they could. The time taken to finish one full circuit in the clockwise and then the counterclockwise direction was recorded.

No studies have measured dynamic postural stability in participants wearing VFFs or going barefoot using a modified SEBT or during a timed test. Thus, the aim of this study was to assess dynamic standing balance of participants BF, wearing VFFs, or athletic shoes using these two tests. The null hypothesis was there will be no significant difference between variables and shoe wear. The expectation was that participants wearing athletic shoes would reach further and perform time tests faster than when these same participants wore VFFs or went barefoot. We also expected that, because VFFs are considered a barefoot shoe, results when participants were BF or wore VFFs would be the same.

METHODS

Participants

Volunteers needed to meet the age requirement of 18-30 years. Exclusion of volunteers occurred for any of the following reasons: significant injuries or surgeries within the last 12 months, pregnancy, any history of or current cardiac, musculoskeletal, or neurological illness. All volunteers owned athletic shoes, and none had any experience wearing barefoot style shoes. 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 (1). This study was approved by the university's Institutional Review Board. All participants provided informed consent prior to participation per university guidelines. This study adhered to the ethical policies set by the Editorial Board of this journal (18). Volunteers brought their athletic shoes to the lab.

Protocol

Volunteers were requested to refrain from exercise 24 hours prior to their test appointment to prevent effects of fatigue. In addition, to be admitted to the study, volunteers had to answer "no" to the following questions on the day of testing: are you experiencing any pain in your lower extremities, do you have any foot or ankle conditions (e.g., open sores, cuts), are you feeling light-headed, dizzy or faint? To standardize the protocol, the stationary leg for all testing was the left; the right was the dynamic leg. The modified SEBT was always performed first.

The right leg length was measured in supine from the anterior superior iliac spine to the medial malleolus to be used later in standardizing reach scores. The order of footwear use was drawn from a computer-generated list. All participants wore the same model of VFF. The fit manual at the Vibram web site guided each participant's VFF size (30). After donning VFFs, participants were only allowed to move the feet within the VFFs to make sure that all the toes were in the correct place.

Participants warmed up on a stationary bike for 5 minutes at a self-selected speed while watching two short instructional videos explaining the basics of the study. Upon dismounting the bike, participants completed static stretching of quadriceps, hamstrings, and gastrocnemius for 2 minutes. Modified SEBT: The same researcher demonstrated the performance of this test. This occurred before the first trial and the participant performed three

trials for familiarization in the first assigned footwear. The placement of the stance foot (the left) was with the ball of the foot placed on the intersection of the anterior/posterior line (A/P) and a line perpendicular to the A/P line. The big toe was in line with the A/P tape. While reaching, participants could bend the trunk, hips, and/or left knee and plantar flex the reaching ankle but were required to keep hands on the hips (first web space on iliac crests with palms facing down). The reaching right leg aligned with the left medial malleolus on each return to center but did not touch the ground.

For each reach, participants reached as far as possible, tapped the big toe down, and raised it, hovering above the tape at the spot for approximately one second for their own count. One researcher immediately marked this spot. Participants brought the reaching foot back to the starting position, touching it to the medial malleolus of the left foot until told to reach again. This was repeated for all nine trials for each type of footwear. The direction of reach was the same for all footwear: three reaches each: anterior, posteromedial, posterolateral. Trials were repeated if the participants moved hands off the hips, moved the feet from the starting position or fell.

Timed test: Still wearing the footwear for the first balance test, the timed test was demonstrated for the participant and he/she practiced once. The starting position was the same as the modified SEBT. Participants made a circle first clockwise and then counterclockwise. Participants reached toward the first spoke at the anteromedial position, tapped down, immediately raised the foot and returned the reaching foot to start. Next, the anterior position was tapped. This pattern continued until 6 spokes of the wheel had been touched: anteromedial to posterior. To touch the remaining positions, the reaching leg moved anteriorly across the left leg for the posteromedial and medial positions. Then the participants re-touched the first spoke (anteromedial position) once again, so that motion around the "clock" was complete (figure). Participants were not allowed to rest before repeating the test in a counterclockwise manner. The time taken to finish one full circuit in each direction was recorded. Participants repeated the reaching protocol and the timed tests with the two other footwear types in the assigned order.

Statistical Analysis

G*POWER 3.1 (Universitat Kiel, Germany) was used in a power analysis to determine that 28 participants were needed in the present study for a power of 0.80, with an effect size of 0.5 and an $\alpha = 0.05$. Reach distances were normalized to limb length by calculating the maximal reach distance (%MAXD) using the formula (excursion distance/limb length) X 100 = % MAXD (22). Data from the modified SEBT were averaged for the three trials for each type of footwear. Three separate repeated measures analysis of variance including *post hoc* analysis with Bonferroni's correction was used to compare reach scores and timed tests wearing VFFs, athletic shoes and BF for the three reach positions (anterior, posterolateral and posteromedial). The data met the assumption for homogeneity of variance. The alpha level was set at 0.05; SPSS V. 21 was used to analyze the data.

RESULTS

Fifteen individuals who were not study participants took part in intrarater reliability testing prior to starting the project. Intrarater reliability (ICC 3,1) for reach measures under the 3 footwear conditions and directions ranged from .921 to .989 (Table 1). Intrarater reliability (ICC 3,1) for the timed test was .945.

Table 1. Intrarater reliability (ICC $_{3,1}$) for three directions of modified Star Excursion Balance Test in three different footwear conditions.

Footwear	Anterior	Posterolateral	posteromedial
Vibrams	.921	.974	.947
Barefoot	.951	.964	.986
Athletic shoes	.954	.986	.989

Study participants included nine men, mean age 26.2 (+/-5.3 years); 21 females, mean age 25.9 (+/-5.7 years). No participant data were excluded. Participants reached farther in all directions when wearing shoes (Table 2). The differences were significant in all paired combinations of footwear for the anterior direction. Only BF vs. shoes showed a significant difference in the posteromedial direction. Wearing shoes also allowed participants to complete the timed tests most quickly but none of the times was significantly different: VFF,22.0 (+/- 5.1 seconds); BF, 21.9 (+/- 5.5 seconds); shoes, 21.0 (+/- 4.5 seconds). The within-subjects effects p value was 0.063.

Table 2. Means and standard deviations (+/-) and pairwise comparisons between reach and type of footwear, with Bonferroni correction (n = 30).

Reach Percent	Type of Footwear *	Mean reach percent (%) and standard deviation (+/-)	p value	95% confidence interval for difference
Anterior	VFF and BF	76.6 (+/-8.4); 76.3 (+/-7.0)	1.00	-1.673 to 1.643
	VFF and AS	76.6 (+/-8.4); 79.6 (+/-8.5)	.000	-4.854 to - 1.804
	BF and AS	76.3 (+/-7.0); 79.6 (+/-8.5)	.000	-5.071 to -1.567
Posterolateral	VFF and BF	89.7 (+/-12.6); 90.2 (+/-11.6)	1.00	-2.735 to 1.846
	VFF and AS	89.7 (+/-12.6); 92.2 (+/- 12.3)	.087	-5.139 to .257
	BF and AS	90.2 (+/-11.6); 92.2 (+/- 12.3)	.146	-.468 to 4.460
Posteromedial	VFF and BF	79.6 (+/- 13.5); 78.0 (+/-12.9)	.538	-1.323 to 4.450
	VFF and AS	79.6 (+/- 13.5); 82.3 (+/-13.9)	.096	-5.780 to .345
	BF and AS	78.0 (+/-12.9); 82.3 (+/-13.9)	.003	-7.264 to -1.298

Note. * VFF =Vibram FiveFingers, BF=barefoot, AS=athletic shoes

DISCUSSION

The study's results confirmed the hypothesis that measures of dynamic balance in VFFs would be similar to BF adding evidence that VFFs are much like going barefoot. The results also suggest that VFFs could be used for practicing dynamic balance activities as part of recommended programs to transition from running shod to running BF. At least 4-8 weeks of transition training, incorporating non-running and non-running activities, is recommended (24, 31). Included in the non-running activities are lower extremity proprioception exercises

including ankle range of motion on fixed and dynamic surfaces and double and single leg stance activities. Kelly et al demonstrated that unipedal BF stance, required in the tests undertaken in this study, increases activation of plantar intrinsic foot muscles more than double limb stance (16). Wearing VFFs during these activities may improve ankle joint and intrinsic foot strength, a necessity in BF running (28,29).

No reports are available comparing participants who wore athletic shoes, VFFs and went BF using the SEBT or the YBT. Double limb static balance with eyes closed was best when young, healthy subjects wore shoes compared with wearing VFFs or going BF (26).

The evidence is unclear about the effect the standing/walking surface and type of footwear has on dynamic balance. Hosada et al (14) found that going BF proved best in maintaining bilateral stance for dynamic balance measures in healthy, young adults who also stood on shock absorbing surfaces and in sandals. Shock-absorbing surfaces of only 5 mm. impaired balance reactions when the body was perturbed in perpendicular and horizontal directions. The authors concluded that thicker soles might inhibit sending of information from receptors of the sole and around ankle joints and from muscle spindles in muscles around this joint. This, in turn, resulted in decreased reaction speed and strength compared to going barefoot (14). However, in a test of dynamic balance while walking on a balance beam, subjects who wore thin-hard soled shoes stepped off the beam or used one foot for balance more than when they were BF. These results did not change regardless of sole thickness or hardness (21).

Wearing VFFs may change proprioceptive input from the foot when balance reactions are tested. Squadrone and Gallozzi found VFFs are more likely to impart a correct estimation of surface slope while subjects stood on one foot or while ran on a treadmill compared to wearing athletic shoes. They hypothesized that foot position is more impaired in athletic shoes than in VFFs (27). Shinohara and Gribble (25) studied postural control in physically active adults wearing a 5-toed sock (analogous to VFFs), a regular sock, and BF in static single leg stance activities. The authors hypothesized that wearing a 5-toed sock would improve balance because of the novel tactile sensation between the toes. However, no significant differences were found in any variables for any condition.

This study is not without limitations. Only healthy, young volunteers without injury participated. Results from individuals with acute ankle injuries, those prone to chronic ankle instability, or those with other lower extremity musculoskeletal conditions may differ from current findings.

The novelty of wearing VFFs may have been a distraction. Participants were only experienced in balancing while wearing footwear such as while walking, running or playing a sport. 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. However, uniform pressure and even fit around each toe in VFFs is not possible. This is especially true in the 4th and 5th toes. Nyska et al (19) recommend that subjects be given 10 days to train in new footwear to allow accommodation. None of our participants had

experience wearing VFFs, but this new sensation did not appear to interfere with the outcomes of these balance tests.

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 (1). Participants wore different brands and styles of athletic shoes, thus, heel counter height, sole thickness/wear and hardness varied. Some participants wore socks with their shoes; others did not. No participant used an orthotic insert.

Results may have been different if more participants were enrolled or were allowed to identify the dynamic leg as the one with which they would kick a ball. Barone et al found that soccer players, compared to basketball players, windsurfers, and sedentary young adults, had better static balance in unipedal stance on the nondominant leg. They attributed this to the kicking skills required in this sport (2).

Another limitation may have been the use of shoes while performing the modified SEBT. Plisky etal in their reliability study of the YBT® had male collegiate soccer players wear shoes while reaching in anterior, posteromedial and posterolateral directions (20). For participants who were not involved in a sport, the mean percent reach for barefoot participants using the SEBT anterior, 79%; posteromedial, 90%; posterolateral, 81% (13). These results are similar to our results (table 2).

Future research should use electromyography to assess these muscular changes in the stance leg while participants perform recommended single leg exercises. Participants should be provided with the same type of athletic shoe. A larger sample or a less homogenous sample may lead to different results. Other tests, such as walking on a balance board, standing on a wobble board, introducing outside perturbations, could also be implemented. Participants with conditions such as chronic ankle instability or knee or hip conditions that may affect balance should also be included.

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