

## THE EXAMINATION OF ANKLE JOINT MOTION BETWEEN BAREFOOT AND MINIMALIST RUNNING SHOES DURING GAIT CYCLES

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Studying gait analysis with particular running shoes is extremely important because the ankle and foot serve as the foundation of structural balance, support, and propulsion. In this study Vibram FiveFingers and Nike Free Run minimalist shoes were chosen because of their popularity and uniqueness. During the testing each participant ran 30 s at the speed of 3 m/s on a flat treadmill for the FiveFingers shoe, Free Run shoe, and barefoot condition. The gait cycles of heel strike, mid support and toe off were examined. In this study no statistical significant increase or decrease in dorsiflexion or plantarflexion angles was observed in the Nike Free Run or Vibram FiveFingers in any phase of gait. This study suggests that both types of minimalist footwear do “mimic” barefoot running because they do not hinder a runner’s range of motion in the ankle joint while running

**KEY WORDS:** dorsiflexion, heel-strike, lower extremities, plantarflexion.

**INTRODUCTION:** Gait is the pattern of movement in animals or humans of the limbs. Without an understanding of the basic human movements of both walking and running, the purpose of running shoes cannot fully be determined. Running shoes have recently been designed to mimic barefoot walking or running, and they are marketed with promises that runners will benefit from the effects of “barefoot running”. Researchers argue that barefoot running allows the body to optimize the impact of vertical ground reaction forces through natural foot motions (Paquette, 2010). While research has been conducted in this field, few studies were able to conclude whether these shoes enable you to perform better or if they hinder performance. Lieberman et al. (2010) noticed that running barefoot or in minimalist shoes may protect the lower extremities from injury. On the contrary, Nigg (2009) suggested that minimalist shoes do not mimic barefoot running or have a lower injury incidence in comparison to shod running. Since the research on barefoot running is inconsistent, it is important to continue this area of research in examining the running gait in various shoes. Studying gait analysis with particular running shoes is extremely important because the ankle and foot serve as the foundation of structural balance, support, and propulsion (Utz-Meagher, Nulty & Holt, 2011). Currently on the market, Vibram FiveFingers and Nike Free Run shoes are marketed as two types of minimalist footwear, and these types of footwear may decrease the risk of running injuries as compared to traditional well-cushioned running shoes (Goss & Gross, 2012). Goss & Gross (2012) also recognized that traditionally shod runners had a greater likelihood of reporting injuries than runners in minimalist shoes in the lower extremities. Those whom ran in minimalist shoes experienced fewer injuries in the kinematic chain of the hip, knee, lower leg, ankle, and foot according to an online survey of 2,509 runners aged from 18 to 50 years old. These minimalist running shoes allow the runner to land on the balls of their feet which in turn generates less impact. The intent of these minimalist running shoes is to stimulate a forefoot striking pattern using the feeling of “being barefoot” yet still providing protection of a shoe. The way that the athlete runs however is dependent on their own running patterns, and it is questionable if all athletes will switch to this “forefoot running pattern”. Those who did switch to a forefoot strike style showed greater plantarflexion, which helps performance by absorbing the vertical ground reaction forces of running (American Council on Exercise, 2011). These minimalist shoes are significant to the biomechanics of running because they allow the body to imitate barefoot running by reducing running injuries while still providing protection from the elements. The purpose of this study was to investigate the angles of dorsiflexion and plantarflexion while running on the treadmill

during the heel strike, mid support and toe off phases of gait between the minimalist shoes (Vibram FiveFingers and Nike Free Run) and barefoot condition.

**METHODS:** Five female elite distance runners of the age of  $21 \pm 1$  year were recruited to participate in the study, and all participants had more than 5 years of competitive running experience. In addition, all participants had a heel strike landing pattern with the traditional cushioned running shoes. Participants were free of injury and they were fully briefed on the protocols of the study. This research study was approved by the institutional ethics review board, and written consent form was obtained from all participants prior to the testing. All participants wore black tightfitting running clothes and arrived at the Exercise Physiology Laboratory. In this study Vibram FiveFingers and Nike Free Run minimalist shoes were chosen for testing because of their popularity and uniqueness. Each participant warmed up with their regular warm up routine on a suspended track. After warm up, each participant was given a chance to warm up in each type of footwear, allowing them to become familiar with them. This process enabled participants to feel comfortable with their shoes. During the testing each participant ran 30 s at the speed of 3 m/s on a flat treadmill for the FiveFingers shoe, Free Run shoe, and barefoot condition. The running speed of 3 m/s was selected due to its prevalence in a similar previous running research study, which allowed for a comparison between both studies (Telhan et al., 2010). The authors recognize that the selection of running speed was not race pace, but it was selected due to its incongruence with other studies. The speed was chosen to ensure the difference in shoes was the only factor to influence the results. Participants had five minutes to rest between each type of footwear. Data collection was concluded in one day for an hour in duration for each participant. Three joint reflective markers were placed on the right side of the body at the knee (lateral epicondyle of femur), ankle (lateral malleolus) and toe (base of fifth metatarsal). A JVC (Model: GR-D371V) video camera was positioned to capture the sagittal view of running motion at 60Hz, and a 650W artificial lighting was used to assist in joint marker identification. A standard two-dimensional kinematic analysis was conducted for ankle dorsiflexion and plantarflexion angles at the heel strike, mid support, and toe off with video graphic analysis for each type of footwear and barefoot condition. Five gait cycles were selected for analysis for each participant. Each gait cycle began with the heel strike and concluded at the toe off. A total of 225 trials were recorded, and all video trials of the gait cycles were then transferred onto a computer in the Biomechanics Lab for gait analysis using Ariel Performance Analysis System (APAS). A digital filter function was applied to data at 7 Hz. A two-way (3 types running condition x 3 gait cycles) repeated measures ANOVA test was conducted at  $\alpha = 0.05$  and followed by t-test with Bonferroni adjustment if a significant difference was found. All statistical analyses were conducted with SPSS (v. 18) software.

**RESULTS AND DISCUSSION:** The results of this study showed no statistical significant difference in the ankle joint (dorsiflexion or plantarflexion) between all three types of running condition in each phase of the gait cycle, Table 1. In this study the Vibram FiveFingers shoe showed the smallest plantarflexion angle at heel strike and toe off, and the largest dorsiflexion angle during mid support. On the other hand, Nike shoe showed the greatest plantarflexion angle at toe off and the lowest dorsiflexion angle at mid support. Additionally, all runners demonstrated a heel-strike landing pattern during all three running conditions.

**Table 1**  
**Ankle Joint During Various Phases of the Gait Cycle. Data are Means (SD).**

	Heel Strike	Mid Support	Toe Off
Barefoot (°)	106.8 (11.4)	83.1 (3.7)	128.4 (4.9)
Vibram (°)	100.7 (3.6)	81.1 (6.0)	124.5 (5.2)
Nike (°)	104.3 (11.1)	86.0 (2.5)	130.8 (6.4)

There were no significant differences found between both types of minimalist footwear because they are constructed with similar materials and display lightweight characteristics. The slight differences in their construction had minimal influence on the dorsiflexion or plantarflexion angles. Both types of minimalist shoes allow the ankle joint to move unrestricted when comparing to the barefoot running. According to Rothschild (2012), barefoot runners are able to change from a rearfoot heel striking pattern to a forefoot or midfoot striking pattern because of a larger plantarflexion range of motion at the ankle. When transitioning from shod to barefoot, there was no increase in plantarflexion range of motion in the ankle joint seen in the five female elite runners. During this study, there was no significant difference in dorsiflexion or plantarflexion between shod and unshod. Some possible reasons why there was no difference between shod and unshod in the ankle joint while running is because minimalist shoes were worn, and it is possible Rothschild (2012) had used traditional running shoes instead of minimalist footwear. This research study supports Rothschild (2012)'s findings that minimalist shoes are a good transition from running shod to running barefoot, as well as minimalist shoes effectively mimic barefoot condition. In terms of ankle motion, Utz-Meagher, Nulty & Holt (2011) concluded that there was a significant decrease in the foot angle while running barefoot, which enabled the runners to land on midfoot or forefoot. However, there was no change in striking pattern or a significant change in dorsiflexion or plantarflexion angles observed in this research study. A possible explanation may be because runner's in Utz-Meagher, Nulty & Holt (2011) wore a different type of minimalist footwear, or an adaptation period is needed to observe a change in running pattern. In this study Vibram FiveFingers shoe showed the smallest plantarflexion angles and largest dorsiflexion angles throughout the gait cycle. For the mid support and toe off phases of gait, the barefoot condition displayed angles similar to the Vibram and Nike shoes. These findings allow us to determine that both types of footwear "mimic" barefoot running because they display similar angles of plantar and dorsiflexion during the gait cycle.

**CONCLUSION:** In this study the ankle motion was examined with five elite female runners, and each runner ran in two types of minimalist shoe (Nike Free Run and Vibram FiveFingers) and in barefoot condition on a flat treadmill at 3 m/s. The results of this research study conclude that minimalist running shoes do in fact "mimic" barefoot running in terms of ankle dorsiflexion and plantarflexion motions. A similar range of motion at the ankle joint between two types of minimalist footwear and barefoot running condition was observed at the heel strike, mid support and toe off of the gait cycle. There were no statistical significant differences found between the various phases of gait in the barefoot or shod condition. Overall, performing in barefoot, Vibram FiveFingers, or Nike Free Run shoes does not hinder the performance at the ankle joint while running. Therefore, any of these shoes would be an appropriate choice when looking to select footwear for treadmill running. Future studies are warranted to examine the performance of the same footwear condition against itself on various inclines and various running velocities.

#### **REFERENCES:**

- American Council On Exercise. (2011). ACE evaluates benefits of vibram fivefingers shoes for barefoot runners. *ACE Fitness*.
- Goss, D.L., & Gross, M.T. (2012). Relationships among self-reported shoe type, footstrike pattern, and injury incidence. *US Army Medical Department Journal*.
- 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.
- Nigg, B. (2009). Biomechanical considerations on barefoot movement and barefoot shoe concepts. *Footwear Science*, 1(2), 73-79.

Paquette, M., Baumgartner, L., & Songning, Z. (2010). Are the vibram fivefingers a functional alternative to barefoot running in inexperienced barefoot runners?. *Conference Proceedings Of The Annual Meeting Of The American Society Of Biomechanics*, 767-768.

Rothschild, Carey. (2012). Running barefoot or in minimalist shoes: evidence or conjecture? *Strength and Conditioning Journal*, 34(2), 8-17.

Telhan, G., Franz, J. R., Dicharry, J., Wilder, R. P., Riley, P. O., & Kerrigan, D. (2010). Lower limb joint kinetics during moderately sloped running. *Journal of Athletic Training*, 45(1), 16-21.

Utz-Meagher, C., Nulty, J., & Holt, L. (2011). Comparative analysis of barefoot and shod running. *Sport Science Review*, 20(3/4), 113-130.

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