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# Initial Response of Mature, Experienced Runners to Barefoot Running: Transition to Forefoot Strike

Scott M. Mullen, M.D., E. Bruce Toby, M.D., Damon E. Mar, Ph.D., Megan Bechtold, DPT, OCS, Bryan G. Vopat, M.D., Heath Melugin, M.D., Terence E. McIff, MBA, Ph.D.
University of Kansas Medical Center, Department of Orthopedics and Sports Medicine, Kansas City, KS

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## ABSTRACT

**Introduction.** Forefoot strike has been advocated for many runners because of the relatively lower impact and push-off forces compared to a heel strike. The purpose of this study was to explore the ability of mature (> 30 years old), experienced runners to transition from a heel foot strike to a forefoot strike when first introduced to barefoot running on a treadmill. We hypothesized: 1) mature runners who heel strike while wearing traditional training shoes would persist in heel striking immediately following a switch to barefoot, 2) mean shoe heel-to-toe drop would be significantly greater in runners who persist in heel striking when running barefoot compared to those who transition to a forefoot strike pattern, and 3) there would be a significant decrease in heel striking in the barefoot condition as running speeds increased.

**Methods.** This was a controlled crossover laboratory study. Thirty-three experienced runners (average 23.4 miles per week) with an average age of 45.6 years were recruited for this study. The participants first ran in their standard running shoes and subsequently barefoot. A motion capture system was utilized to detect and analyze any transition from heel strike to forefoot strike made by study participants.

**Results.** Of the 26 participants who were classified as heel strike runners in their running shoes, 50% (13/26, p = 0.001) transitioned to forefoot strike when changing from running in shoes to running barefoot.

**Conclusions.** The injuries associated with transition from standard running shoes to barefoot running or minimalist shoes may be influenced by the persistence of heel striking in mature runners. Older experienced runners may have limited ability to transition from heel to forefoot striking when first introduced to barefoot running. Mature runners should be cautious when beginning a minimalist shoe or barefoot running regimen. ***Kans J Med 2019;12(4):117-120.***

## INTRODUCTION

Running is one of the most popular sports in the United States with 50 million or greater participants in 2011 and 17 million running events in 2015,[1,2] many of whom are older and have a long history of running. Over the last decade, there has been increased enthusiasm in the running community for barefoot running, or running with so-called "minimalist shoes". The touted advantages of forefoot strike include a more natural running style that allows for shock absorption by the muscles and ligaments of the foot resulting in less impact to the joints of the ankle, knee, and hip.[3-5] This would be important for older runners who continue running for fitness but wish to protect their joints. While many runners may have tried these styles simply out of curiosity, most people are interested in these styles because of a belief that they lead to fewer injuries and/or allow for a more "normal gait". There is, however, little evidence in the literature that barefoot running decreases the risk of injury. Barefoot running has been shown to reduce stride length, induce greater plantar flexion in footfall, and promote a forefoot strike.[6]

Age, experience, and habitual running style may have an effect on a runner's ability to achieve a forefoot strike when first introduced to barefoot running. Lieberman et al.[3] found that, unlike those who grew up running barefooted, those who have run habitually in shoes do not transition readily to forefoot strike when running barefooted. Those who grew up running barefooted continue in a forefoot strike even when in a shoe. In contrast, a study looking at competitive adolescent runners showed that a majority of these athletes exhibited a forefoot strike rather than a heel strike when running barefoot or in minimalist track flat shoes, particularly at higher speeds.[7] The findings indicated that adolescent runners adapted quickly when changing from traditional trainer shoes to minimalist shoes or barefoot conditions. It may be that younger runners are more able to transition to a forefoot strike than older, more mature runners.

This study investigated the initial response of mature (> 30 years old), experienced runners, who normally run in traditional shoes with thick, cushioned heels, to barefoot running. The hypotheses were: 1) mature runners who heel strike while wearing traditional training shoes would persist in heel striking immediately following a switch to barefoot, 2) mean heel-to-toe drop would be significantly greater in the runners who persist in heel striking when running barefoot compared to those who quickly transition to a forefoot strike pattern, and 3) there would be a significant decrease in heel striking in the barefoot condition as running speeds increased.

## METHODS

Local participants from the greater Kansas City area and Lawrence, Kansas with greater than 10 years of running experience and over the age of 30 were recruited for this study with approval from the Human Subjects Committee at our institution. Written informed consent was obtained from each participant prior to data collection. A total of 33 test participants (10 women and 23 men) were recruited for the study. Participants were asked to bring their usual running shoes. Data measured or collected on all participants included: heel-to-toe drop of their running shoes, weight, height, body mass index (BMI), age, injury history, and number of miles ran weekly.

A standard exercise treadmill (95T, Life Fitness, Schiller Park, IL) was used in this study. Each participant was allowed a five-minute warm-up. After warm-up, each participant ran for 30 seconds at three different speeds on the testing treadmill: 6, 7, and 8 miles per hour for women and 7, 8, and 9 miles per hour for men. Each participant ran

the three speeds consecutively, first in their shoes, then barefoot with a brief rest period in between. One male participant was unable to run at the top speed.

The foot strike data were collected using a motion capture system (Dartfish, Alpharetta, Georgia). The foot strike type for each participant was evaluated visually over ten full gait cycles near the end of the 30 second duration, under each shod condition, and at each speed. All gait analysis was done using each participant's left foot. All gait data were collected and analyzed by a single examiner (blinded to subject and speed) skilled in running kinematics, gait analysis, and with using the motion capture system. If the 5$^{th}$ metatarsal was visualized to contact the treadmill before or at the same time as the heel, the strike was defined as a forefoot strike. Forefoot and mid-foot strike were not differentiated in this study.

Individuals who heel struck greater than half the time across all speeds while running in shoes were categorized as heel strikers and those who did so less than half the gait cycles across all speeds as forefoot strikers. Only individuals who were classified originally as heel strikers while wearing shoes, then shifted to forefoot striking while barefoot were considered to have transitioned. The non-transition rate was defined as the number of runners in a group who did not transition to mid or forefoot striking divided by the total number in that group.

Shoe heel-to-toe drop was measured on each participant's left running shoe. Measurements were made using a digital caliper with a custom feeler arm at the points of maximum heel thickness and the location of the 5$^{th}$ metatarsophalangeal joint (Figure 1). The measurements were taken at a fixed touch force of 10 Newtons to account for the variance in sole stiffness and curvature across the shoe types. Each measurement was made three times, then averaged before calculating heel-to-toe drop, which was defined as the difference between the heel and metatarsophalangeal height measurements.

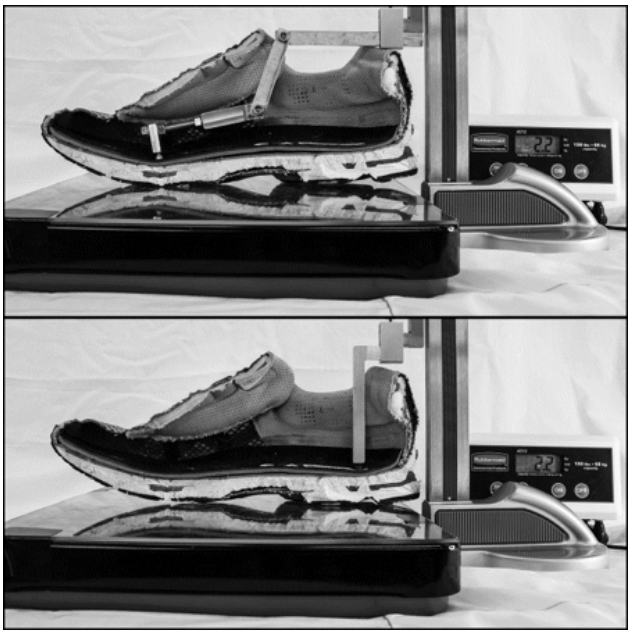

Figure 1. Digital caliper with custom feeler arms used to measure shoe thickness at 5$^{th}$ metatarsal (top) and heel (bottom) to determine heel-to-toe drop at a fixed touch force of 2.25 pounds (10 N).

An independent sample t-test was used to evaluate heel-to-toe drop between genders. Pearson's chi-square tests were used to compare global and individual differences in shod and barefoot percentages at each speed. Logistic regression was used to identify possible predictors of non-transition including: heel-to-toe drop, age, weight, height, BMI, sex, and weekly running distances. Analysis of covariance (ANCOVA) was used for testing of mean difference in heel-to-toe drop and other independent variables between those who transitioned and those who did not transition.

## RESULTS

The mean subject age was 46.6 years (51.5 for women and 44.4 for men) and ranged from 30 to 68 (Table 1). The participants reported an average running distance of 23.4 miles per week (range of 3 to 90 miles per week). All were road runners who wore standard running shoes with positive heel-to-toe drop.

**Table 1. Subject demographics, mean (standard deviation).**

| | Men | Women | Combined |
|---|---|---|---|
| Age (years) | 44.4 (12.2) | 51.5 (11.4) | 46.6 (12.2) |
| Heel-to-Toe Drop (mm) | 7.5 (4.2) | 11.6 (5.9) | 8.8 (5.1) |
| Average Running Distance (miles/week) | 22.6 (19.0) | 25.1 (11.6) | 23.4 (16.7) |
| Body Mass Index | 23.7 (1.9) | 21.2 (2.6) | 22.9 (2.4) |

There was an overall significant decrease in percent of heel strikers between the shod and barefoot conditions ($p < 0.001$). The mean combined gender heel strike with and without shoes for each running speed is shown in Figure 2. The mean heel strike for females and males are shown separately in Figures 3 and 4, respectively.

Though participants were classified as either heel striking or forefoot striking depending on the majority of the ten strikes observed, most subjects were consistent in one pattern across all ten strikes. Only 5 of 33 had a mixed strike pattern during at least one trial while barefooted and only 3 of 33 had a mixed strike pattern during at least one trial while shod. In all cases, mixed strike patterns occurred at higher speeds as a transition away from heel strike was seen.

No runners transitioned from forefoot strike to heel strike when switching to barefoot running. Of all mature study participants, 79% were categorized as heel strikers (70% of females, 7/10, and 83% of males, 19/23) while running in shoes. Among these heel strikers, 50% overall (13/26, $p < 0.001$) were categorized as having transitioned to a forefoot strike when switching to running barefoot.

Thirty percent (3/10) of women and 43% (10/23) of men maintained a heel strike across all speeds regardless of whether running in shoes or barefoot. These percentages included those who were forefoot strikers both while in shoes and while barefooted. Alternatively, 30% (3/10) of women and 13% (3/23) of men maintained a forefoot strike across all speeds regardless of whether they ran in shoes or barefoot. For women, 70% ran with a heel strike while running in shoes across all speeds. For women, there was no change in foot strike

classification with speed over the range of 6, 7 and 8 mph. For males, 83% ran with a heel strike at the slowest speed compared to 77% at the fastest speed while wearing shoes. These numbers for males decreased from 50% (11/22) for slowest speed to 41% (9/22) for the fastest speed during barefoot conditions (n = 22 because one male did not complete the fastest running trial either barefooted or shod). Only three of the mature runners demonstrated a change to forefoot strike with increasing speed in either the barefoot or shod conditions. Gender alone was not found to be predictive of the type of foot strike while wearing shoes (p = 0.420).

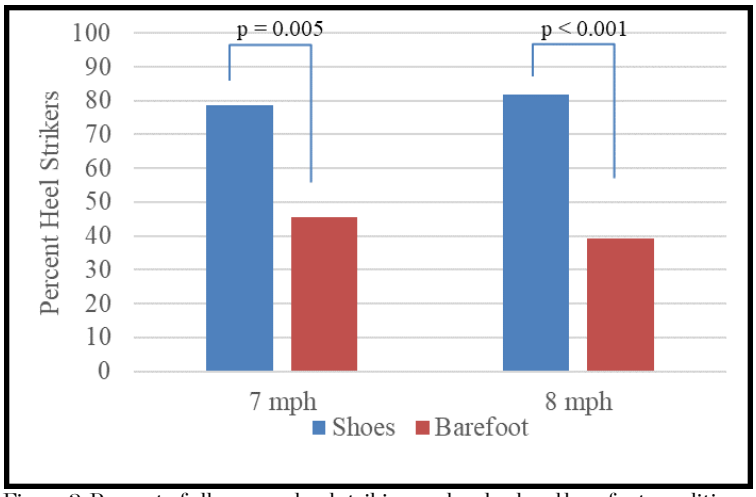


Figure 2. Percent of all runners heel striking under shod and barefoot conditions (p values from Pearson's chi-square test; n = 33).

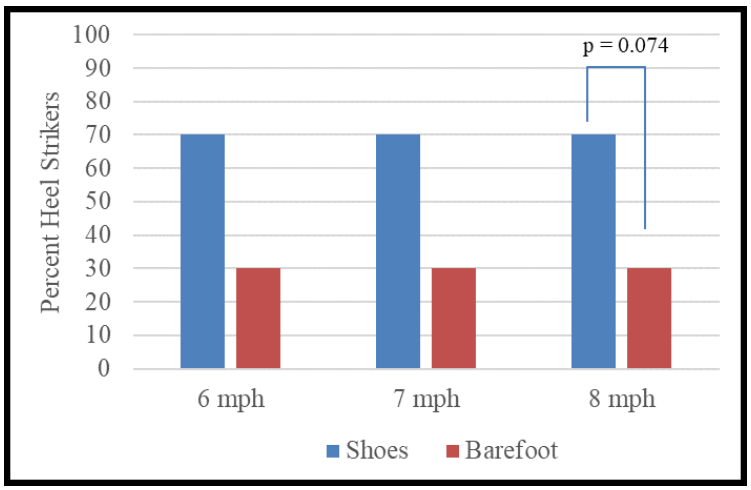


Figure 3. Percent of mature female runners heel strikes in shod and barefoot conditions (p values from Pearson's chi-square test; n = 10).

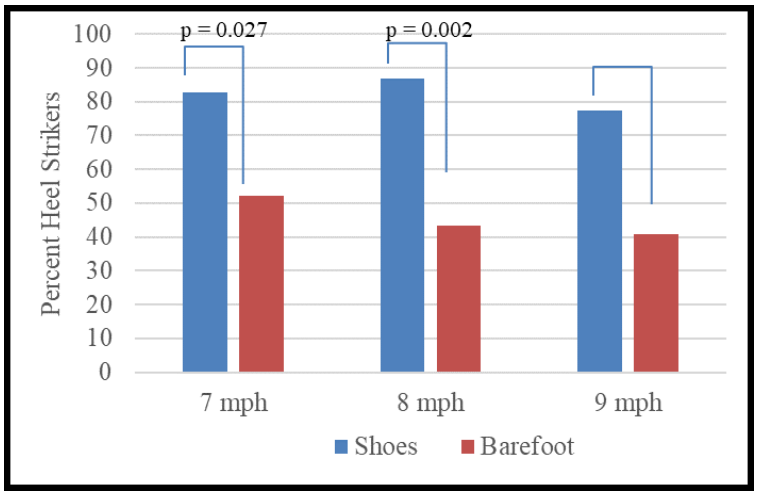


Figure 4. Percent of mature male runners heel strikes in shod and barefoot conditions (p values from Pearson's chi-square test; n = 23 for speeds of 7 and 8 mph; n = 22 for speed of 9 mph).

Seventy-nine percent of the subjects utilized traditional training shoes with greater than 5 mm of heel-to-toe drop (90% of females and 75% of males). Females had a significantly larger mean heel-to-toe drop than males (mean 11.7 mm for females and 7.5 mm for males; p = 0.016). Heel-to-toe drop was not an important predictor of heel striking when running in shoes (p = 0.772). Heel-to-toe drop appeared to be more predictive of heel striking (non-transitioning) while running barefooted (p = 0.097) where the larger heel-to-toe drop was associated weakly with an increased likelihood of transitioning to a forefoot strike (p = 0.061). The mean heel-to-toe drop for those who transitioned was 10.57 mm while the mean for those who did not transition was 7.24 mm. Lower BMI also appeared mildly predictive of non-transitioning (p = 0.059). No evidence was found that, within our sample of mature runners, age, gender, or weekly running distance were good predictors of transitioning to fore foot strike.

## DISCUSSION

The primary goal of the study was to investigate the ability of mature, experienced runners to transition immediately to forefoot strike from heel strike when introduced to barefoot running, particularly those runners that normally exhibit a heel strike pattern while running in shoes. The results demonstrated that 79% of the total participant group were heel strikers when running in shoes and 50% of those heel strikers persisted in a heel strike pattern when switching to the barefoot condition. This is concerning for experienced runners who are heel strikers and begin running barefoot. With 50% of runners continuing to heel strike, this exposes a significant number of these runners to potential injury.

Previous studies have reported that 75 to 90% of habitually shod runners strike with their heel when running in shoes.[8,9] Hashish et al.[10] reported a 36% non-transition rate among a group of 19 to 40 year old habitual rear-foot strike runners (n = 22) running at their self-selected speed. Both that study and our study suggested mature, experienced runners, in general, may have greater difficulty transitioning to a forefoot strike pattern when running in more minimalist running shoes or in the barefoot condition, even at higher speeds. In contrast, Mullen et al.[7] found that among elite adolescent runners, 80% exhibited a heel strike pattern while running in classic trainer shoes with large heels

at moderate speeds (7 - 8 mph); however, less than 38% exhibited the same heel strike type when running in the barefoot condition at those same speeds. The heel strike percentages decreased even more at faster running speeds where 11 of 12 of these adolescents ran with a forefoot strike as opposed to a heel strike.[7] Younger, less established runners may have a better ability to transition to forefoot strike while barefoot running than more mature runners.

Our hypothesis that runners with larger heel-to-toe drops would be less likely to transition to a forefoot strike pattern after introduction to barefoot running was not substantiated. In fact, it is likely that with larger numbers the opposite may be found to be true; runners who run in shoes with larger heel-to-toe drops may be more likely to transition. One explanation is that if someone already is running in low heel-to-toe drop shoes and still heel striking, they are less likely to transition to forefoot strike with barefoot running than someone who is heel striking while wearing larger drop shoes. Our last hypothesis that mature runners would be sensitive to running speed and be more likely to forefoot strike as running speed increased also was unsupported by our data. Only 3 of 33 of the mature runners seemed to change foot strike as a function of speed. In the previous study of adolescent runners by Mullen et al.[7] running speed had a clear and significant effect on the type of foot strike. This was not the case with the mature runners. Mature runners may be less able than younger runners to adapt to faster running speeds through changes in their foot strike patterns.

The inability to transition to a forefoot strike when barefoot running can be of concern. This persistence in heel striking while barefoot or wearing minimalist shoes by mature, experienced runners may make them more likely to incur injuries due to the increased forces being applied to the heel without the shock absorber effect of the traditional running shoe or the shock absorption of the foot's muscles and ligaments available with a forefoot strike.[11] Highlighting this concern is the two-fold increase in repetitive injury rates associated with heel strike versus forefoot strike found in a study by Daoud et al.[12]

Our study implied that mature runners may not adjust foot strike pattern promptly when switching to barefoot running as do adolescent runners. Mature runners may have a more established gait and require a longer period of training prior to adapting to a forefoot strike in the barefoot or minimalist shoe condition. Our study, however, did not provide insight into whether this transition eventually will occur on its own, or whether coaching or participation in a training program might encourage the transition.

This study had several limitations. Individuals ran in their own shoes, they were not standardized to a particular shoe type or model. Most study participants had relatively thick heels (79% greater than 5 mm) since they were runners who routinely ran on pavement. There were no master track surface runners or sprinters within this study who might differ from road racers. None of these athletes ran in a track flat or cross-country flat style of shoe, although seven participants ran in shoes with less than 5 mm heel-to-toe drop. Another limitation was that the subjects knew the rationale for the study ahead of time and many, if not all, understood the potential advantages of a forefoot strike. Given this fact, there may have been a bias to forefoot strike, particularly while barefoot, therefore, the actual persistence of heel strikers in the barefoot condition in runners outside of this study may be even greater than the current results indicated.

## CONCLUSIONS

Older experienced runners may have limited ability to transition from heel to forefoot striking when first introduced to barefoot running. Mature runners should be cautious when beginning a minimalist shoe or barefoot running regimen and might consider a gait analysis or coaching to assist them in adopting a forefoot strike style and avoiding injury. Physicians caring for runners should consider the runner's experience and age when treating running injuries or assisting them in a transition to running barefoot.

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