Short-Term Changes in Running Mechanics and Foot Strike Pattern After Introduction to Minimalistic Footwear

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Background: Minimalistic footwear has garnered widespread interest in the running community, based largely on the premise that the footwear may reduce certain running-related injury risk factors through adaptations in running mechanics and foot strike pattern.
Objective: To examine short-term adaptations in running mechanics among runners who typically run in conventional cushioned heel running shoes as they transition to minimalistic footwear.
Design: A 2-week, prospective, observational study.
Setting: A movement science laboratory.
Participants: Nineteen female runners with a rear foot strike (RFS) pattern who usually train in conventional running shoes.
Methods: The participants trained for 20 minutes, 3 times per week for 2 weeks by using minimalistic footwear. Three-dimensional lower extremity running mechanics were analyzed before and after this 2-week period.
Main Outcome Measurements: Hip, knee, and ankle joint kinematics at initial contact; step length; stance time; peak ankle joint moment and joint work; impact peak; vertical ground reaction force loading rate; and foot strike pattern preference were evaluated before and after the intervention.
Results: The knee flexion angle at initial contact increased 3.8° ($P < .01$), but the ankle and hip flexion angles at initial contact did not change after training. No changes in ankle joint kinetics or running temporospatial parameters were observed. The majority of participants (71%), before the intervention, demonstrated an RFS pattern while running in minimalistic footwear. The proportion of runners with an RFS pattern did not decrease after 2 weeks ($P = .25$). Those runners who chose an RFS pattern in minimalistic shoes experienced a vertical loading rate that was 3 times greater than those who chose to run with a non-RFS pattern.
Conclusion: Few systematic changes in running mechanics were observed among participants after 2 weeks of training in minimalistic footwear. The majority of the participants continued to use an RFS pattern after training in minimalistic footwear, and these participants experienced higher vertical loading rates. Continued exposure to these greater loading rates may have detrimental effects over time.

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INTRODUCTION

Running is a common recreational activity, with an estimated 35.9 million participants in the United States [1]. Many of these individuals choose to run because of general health benefits. However, runners are at high risk for musculoskeletal injury [2]. Two of the most common running-related injuries, patellofemoral pain and tibial stress fractures, are significantly more common among female runners [3,4] and have been found in some studies to be associated with the magnitude and rate that vertical impact forces are applied to the body during running [5-9]. A systematic review of the relationship between lower extremity stress fractures and the ground reaction force during running suggests that the

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rate of loading may have a stronger relationship to stress fracture risk than the magnitude of loading [10]. Many factors affect the magnitude and rate of loading during running, including running speed, knee flexion and the ankle dorsiflexion angles at initial contact, stride length, running surface, and footwear [11-17].

Manipulation of a runner's foot strike pattern has been promoted as a mechanism to decrease the magnitude and rate of loading during running [5,6]. A rear foot strike (RFS) pattern is defined by the runner making first contact with the ground with the heel and is typical for 75% of shod runners [18]. However, running with a non-RFS (NRFS) pattern has been promoted as 1 mechanism to reduce the vertical loading rate and running-related injuries [6]. Runners with an NRFS pattern typically land on the midfoot or the forefoot and demonstrate increased ankle plantarflexion and an increased knee flexion angle at initial contact [17,19]. Running with an NRFS also tends to produce a vertical ground reaction force curve similar to a simple parabola, with the vertical impact peak diminished or absent, which may result in a decreased vertical ground reaction force loading rate and increased ankle joint eccentric work [16,19-24].

Some controversy exists regarding the influence of footwear on a runner's preferred foot strike pattern. It has been suggested that the midsole cushion promotes an RFS pattern while running on hard surfaces by limiting pain and proprioceptive and tactile sensory feedback required to promote stride modifications that reduce impact forces [25-27]. In the absence of cushioned footwear, runners may adopt an NRFS strike pattern due to high localized pressure and pain experienced under the heel while barefoot running with an RFS pattern [21]. Indeed, it has been reported that runners who traditionally choose an RFS pattern in shoes with a midsole cushion adopt an NRFS strike pattern (or land more anteriorly on the foot) while running barefoot [28,29]. In further support of the notion that footwear cushion affects running kinematics is the finding that the majority of the runners (18 of 32) who displayed an RFS pattern while running on a soft surface converted to an NRFS pattern when running on a hard surface [30]. However, it also has been reported that many runners accustomed to running with an RFS pattern in shoes with a midsole cushion tend to maintain an RFS pattern while running barefoot [17,24].

Recently, many shoe companies have produced and marketed "minimalistic" footwear. These shoes lack a midsole but do possess a rubber outersole to provide protection to the plantar surface of the foot from the environment. Market demand for these shoes is high among runners. A 2011 survey analysis of runners' interest in barefoot running or in using minimalistic footwear indicates that 76% of runners are at least somewhat interested in running barefoot or in minimalist shoes, 22% of runners have already tried barefoot running, and 30% have previously tried minimalist footwear [31]. This survey also found that runners who attempt a transition to barefoot or minimalist footwear running frequently do so with advice from a friend or a book and that they make the transition in less than 2 weeks [31].

A rapid change in running mechanics that is associated with footwear may result in novel stressors to musculoskeletal tissues, which may promote injury. However, changes in running mechanics associated with the transition to minimalistic footwear are not well understood. The purpose of this study was to examine short-term changes in running mechanics among female runners who typically run in conventional cushioned-heel running shoes as they transition to running in minimalistic footwear. Specifically, we tested for systematic changes in running kinematics and kinetics that may occur, such as increased hip flexion, knee flexion, and ankle plantar flexion, at initial contact, decreased magnitude of the vertical impact peak, increased vertical loading rate, and increased ankle joint eccentric net work. We also examined whether, after 2 weeks of training when using minimalistic footwear, the participants demonstrated temporospatial adjustments to their running technique, such as a decreased step length and stance time. Finally, we tested the hypothesis that the majority of the runners adopt an NRFS pattern after 2 weeks of training in minimalistic footwear.

METHODS

We considered the average vertical loading rate as our primary variable of interest in this study due to the hypothesized relationship of this variable to running-related injuries such as lower extremity stress fractures [10]. For dependent *t*-tests with an α level of 0.05 and a β level of 0.2, we calculated that 17 subjects were necessary to detect changes over time greater than the minimum detectable change for this variable (10.8 body weights/s) [8,32,33]. To account for the potential of dropouts, 19 healthy female runners who were 18-35 years old and who ran at least 10 miles per week were recruited from 3 area universities. Each reported that they traditionally ran for exercise outdoors by using an RFS pattern and cushioned-heel footwear but that they were interested in training barefoot or in minimalistic footwear. Subjects who reported cardiovascular pathology or surgery to either lower extremity in the past 12 months were excluded. Subjects who reported lower extremity symptoms during running that interfered with their desired training schedule over the past 2 years also were excluded. The procedures for this study were approved by our institutional review board, and all the subjects provided informed consent before participation.

Running mechanics and the preferred strike pattern were analyzed before and after a 2-week period during which time the participants trained by using minimalistic footwear. At the initial (baseline) data collection, the participants ran in both conventional cushioned heel footwear (model 629; New Balance, Boston, MA) and minimalistic footwear (Bikila;