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Original article

Heel–toe running: A new look at the influence of foot strike pattern on impact force

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Abstract

Background/Objective: It is important to understand the factors that influence the impact force observed during running, since the impact force is likely to be related to overuse injuries. The purpose of this study was to compare the impact force during running when participants were instructed to use different foot strike patterns: obvious heel strike (Obvious-HS), subtle heel strike (Subtle-HS), midfoot strike (Mid-FS), and fore foot strike (Fore-FS) patterns.

Methods: Participants ($n = 10$, 25 ± 5.7 years, 70.2 ± 12.1 kg, 174.6 ± 7.2 cm) completed four foot strike patterns while running over ground: Obvious-HS, Subtle-HS, Mid-FS, and Fore-FS. Speed was controlled between conditions (random order). Vertical ground reaction forces were recorded (1000 Hz) along with the impact force, peak force, and stance time for analysis. A repeated measures analysis of variance was used to compare each variable across foot strike instructions, with *post hoc* comparisons contrasting Obvious-HS to each of the other conditions.

Results: Impact force was influenced by foot strike instructions, with Obvious-HS being greater than Subtle-HS and Fore-FS ($p < 0.05$) but not different from Mid-FS ($p > 0.05$). The peak force was not influenced by foot strike instructions ($p > 0.05$); stance time was longer during Obvious-HS than during Mid-FS or Fore-FS ($p < 0.05$), but not different from Subtle-HS ($p > 0.05$).

Conclusion: The unique observation of this study was that impact force was different when participants were instructed to run with either an Obvious-HS or a Subtle-HS at contact. Both these foot strike patterns would have been considered rear foot strike patterns, suggesting that something other than which specific part of the foot strikes the ground initially influenced impact force.

Keywords: Foot strike index; Impact force; Running injuries

Introduction

Running is an activity that continues to grow in participation. For example, there were 25,000 people who completed a marathon in 1976, whereas in 2009 there were 467,000 finishers.[1] In 1990, 303,000 people finished half-marathon distance events, whereas in 2009 there were 1,113,000 finishers.[1] There are many reasons that people include running in their exercise routine; unfortunately, running has also been associated with a high risk of sustaining an overuse injury.[2–4]

It has long been considered that the risk of sustaining an overuse injury as a result of running has been associated with the repetitive impact force with each foot strike.[2–4] Thus, it has made sense that a wealth of research has been carried out on shoe design. However, there has yet to be a definitive answer to the type of shoe that will prevent running injuries. In any case, there is an abundance of research on factors that influence impact characteristics during running. For example, it is known that changes in speed,[5–8] stride length,[6,9,10] running surfaces,[7] and running uphill/downhill[11] are factors that influence impact force. Likewise, there is also a general

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acceptance that the manner in which a foot initially strikes the ground, or the "foot strike pattern," is related to the impact magnitude.[8,12–17]

The part of the foot (or shoe) that contacts the ground first is typically used to define an individual's foot strike pattern.[8] Alternatively, if force plate data are available, foot strike patterns can be determined based upon the initial location of the center of pressure within the foot print.[12] Typical descriptions of foot strike patterns are rear foot (aka, heel–toe) strike, midfoot strike (Mid-FS), and fore foot strike (Fore-FS) patterns.[12,18] The operational definition of these patterns is based on dividing the foot into thirds (length wise) and then identifying which part of the shoe strikes the ground initially. However, an experimental procedure may include a visual description only of foot strike patterns to ensure that participants are using a particular pattern, and actual foot strike pattern is not quantified.

There is a wealth of published data on the influence of foot strike pattern on ground reaction forces during running, and it is generally expected that when running with a rear foot strike pattern, an impact force will be observed, whereas when running with a Fore-FS pattern, no impact force will be observed.[12–17,19] However, there is a gap in understanding the influence of how the different ways of striking the ground heel first may influence impact characteristics. Illustrated in Fig. 1 are two examples of foot strikes, both of which would be classified as rear foot strike patterns. Using a simulation model, Gerritsen et al[20] reported that for a rear foot strike pattern, a change in foot angle at contact can influence impact forces.

It may be that the classification of rear foot strike pattern does not capture the essence of factors that influence impact forces. Yet there are no data (beyond simulation data) on comparing impact forces during running with different rear foot strike patterns. Therefore, the purpose of this study was to compare the impact force during running when participants were given different instructions on foot strike pattern. Specifically, they were asked to run with an obvious heel strike (Obvious-HS) and a subtle heel strike (Subtle-HS) pattern. This work was extended to also instruct participants to use a Mid-FS and a Fore-FS pattern. Because it was expected that Fore-FS and possibly Mid-FS would not have an impact force, we extended our analysis to peak force (at midstance) and stance time.

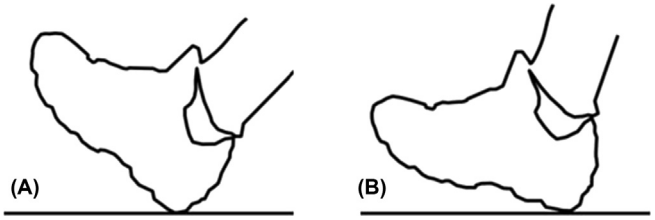

Fig. 1. Illustration of two foot strike patterns that are both considered rear foot strike patterns: (A) The obvious heel strike condition and (B) the subtle heel strike condition.

Methods

Participants

Volunteer participants (n = 10 males, 25 ± 5.7 years, 70.2 ± 12.1 kg, 174.6 ± 7.2 cm) were physically active and free from any injury that would interfere with their ability to run. Upon reporting to the laboratory, participants reviewed and signed the university-approved informed consent.

Instruments

Ground reaction force data were recorded using a force platform (Kistler, Amherst, NY, USA) mounted flush with the floor in the middle of a 14 m runway. Running speed was determined through the use of infrared photocells (Lafayette Instruments, Lafayette, IN, USA) controlling a timer. The photocells were set up 2.44 m apart, with the force platform approximately in the middle.

Procedures

Prior to testing, participants warmed up on a treadmill (AlterG Anti-Gravity Treadmill PRO 200; AlterG Inc., Fremont, CA, USA), and then the test speed was determined. This was done by having participants self-select a running speed that they felt could be maintained for 30 minutes. The treadmill was set with no elevation gain, and the speed display was hidden from view; no instructions were given to participants regarding foot strike. Participants gave the researcher cues to either increase or decrease speed until the desired speed was reached. The self-selected speed was recorded, the treadmill was stopped, and the process was repeated for a total of three times. The test speed was the average of the three self-selected speeds, with the group averaging 3.1 ± 0.6 m/s.

Each participant completed four overground running conditions. Each condition represented a manipulation of instructions for foot strike patterns. For the first condition, participants were instructed to strike the ground with an Obvious-HS (i.e., rear foot strike pattern). For the second condition, participants were instructed to use a Subtle-HS (i.e., rear foot strike pattern). That is, participants were instructed to still use a rear foot strike pattern by striking the ground first with the heel, but to do so more subtly than during the Obvious-HS condition. Operationally, the kinematic difference between Obvious-HS and Subtle-HS was that the ankle was more dorsiflexed at contact during Obvious-HS. For the third condition, participants were instructed to use a Mid-FS pattern by asking them to land with the sole of their shoe flat on the ground. Finally, for the fourth condition, the participants were instructed to use a Fore-FS pattern by asking them to land with the toe region of the shoe. Participants were shown a video of the different foot strike patterns and were given time to practice the patterns prior to testing. During testing, participants were consistently reminded as to the style of which foot strike pattern they were to use and trials were rejected when the tester visually detected that the target strike pattern was not