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Original article

Reduction in ground reaction force variables with instructed barefoot running

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Abstract

Backgound: Barefoot (BF) running has recently increased in popularity with claims that it is more natural and may result in fewer injuries due to a reduction in impact loading. However, novice BF runners do not necessarily immediately switch to a forefoot strike pattern. This may increase mechanical parameters such as loading rate, which has been associated with certain running-related injuries, specifically, tibial stress fractures, patellofemoral pain, and plantar fasciitis. The purpose of this study was to examine changes in loading parameters between typical shod running and instructed BF running with real-time force feedback.

Methods: Forty-nine patients seeking treatment for a lower extremity injury ran on a force-sensing treadmill in their typical shod condition and then BF at the same speed. While BF they received verbal instruction and real-time feedback of vertical ground reaction forces.

Results: While 92% of subjects ($n = 45$) demonstrated a rearfoot strike pattern when shod, only 2% ($n = 1$) did during the instructed BF run. Additionally, while BF 47% ($n = 23$) eliminated the vertical impact transient in all eight steps analyzed. All loading variables of interest were significantly reduced from the shod to instructed BF condition. These included maximum instantaneous and average vertical loading rates of the ground reaction force ($p < 0.0001$), stiffness during initial loading ($p < 0.0001$), and peak medial ($p = 0.001$) and lateral ($p < 0.0001$) ground reaction forces and impulses in the vertical ($p < 0.0001$), medial ($p = 0.047$), and lateral ($p < 0.0001$) directions.

Conclusion: As impact loading has been associated with certain running-related injuries, instruction and feedback on the proper forefoot strike pattern may help reduce the injury risk associated with transitioning to BF running.

Keywords: Barefoot running; Ground reaction force; Loading rates; Mediolateral forces; Vertical stiffness

1. Introduction

Barefoot (BF) running has recently increased in popularity among runners with a perception that it is more natural and may result in fewer injuries. In fact, the top reason runners report for choosing to transition to BF or minimal running is the notion of injury prevention.[1] The potential for a lower risk of injury is postulated based on strengthening of the foot,[2] and changes in loading parameters due to alterations in running pattern associated with BF running.[3]

It has been documented that up to 89% of traditionally shod runners land on their heels or with a rearfoot strike (RFS).[4,5] This strike pattern is associated with an impact transient in the vertical ground reaction force (VGRF), followed by a propulsive peak. The impact transient appears as a distinct change in the positive slope of the VGRF trace, sometimes characterized by a local maximum or impact peak (VIP). The rate of development of the VGRF is referred to as the loading rate (Fig. 1A). High loading rates and impact transients have

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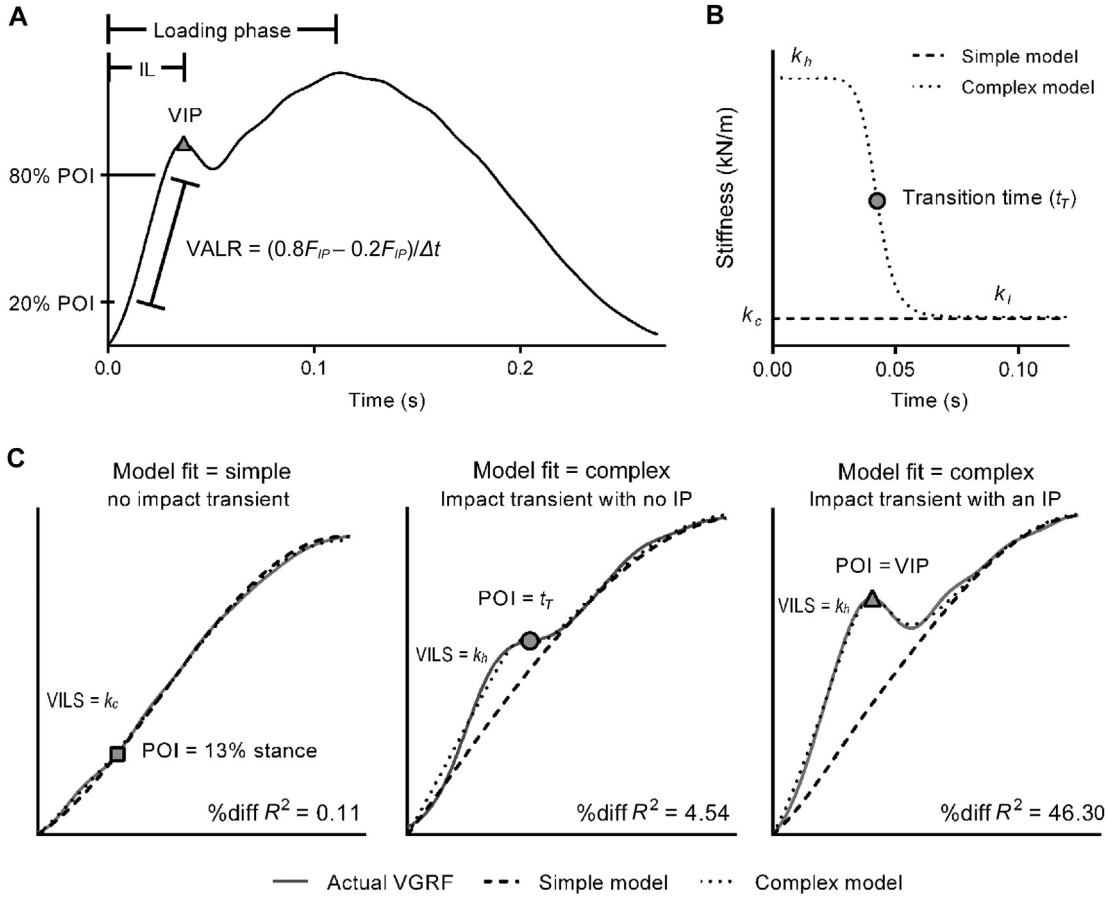

Fig. 1. Complex and simple model fits of the vertical ground reaction force (VGRF). (A) VGRF indicating how the average loading rate (VALR) is computed from 20% to 80% of the force at the point of interest (POI); in this case the vertical impact peak (VIP). (B) Stiffness curve for the simple and complex models. The simple model uses a constant stiffness, k_c, while the complex model has a time varying stiffness that starts with a high stiffness, k_h, during the initial loading (IL) phase and transitions to a low stiffness k_l. (C) Plots of the loading phase of the VGRF curve with both the simple and complex model overlaid for three cases. Case 1: the percent difference for the R^2 values between the two fits (%diff R^2) is <3.0; the simple model is chosen; stiffness during IL is set to k_c; loading rate is computed from 13% of stance. Cases 2 and 3: %diff $R^2 > 3.0$; the complex model is chosen; stiffness during IL is set to k_h. Case 2: There is no impact peak (IP); POI for computing loading rates is the transition time. Case 3: IP present; POI for computing loading rates is the VIP.

been associated with a number of common running-related injuries such as tibial stress fractures,[6] patellofemoral pain,[7] and plantar fasciitis.[8] Most habitual BF runners land on the ball of their foot, referred to as a forefoot strike (FFS) with their foot in a relatively flat orientation.[9] This pattern typically has a single propulsive peak in the VGRF, lacking a distinct vertical impact transient.[10] Elimination of this impact transient is accomplished by reducing vertical stiffness of the body. Vertical stiffness can be assessed using a simple mass spring model[11,12] which works well for an FFS pattern. However, when impact transients are present, a dual stiffness model, such as described by Hunter,[13] should be used.

The influence of strike pattern on the medial and lateral components of the ground reaction force (GRF) is not well established. The lateral GRF may contribute to pronation of the foot, which when excessive has been linked to lower leg and knee pain.[14,15] Changes in the lateral force may influence a runner's tendency to overpronate. Therefore evaluating the change in this parameter between shod and BF runners may lend future insight into the link between these running conditions and certain injuries.

BF running is also associated with a shorter stride and a higher cadence.[16,17] Higher cadence running has been reported to reduce loading at the hip and knee,[18] which may influence injury risk. A higher cadence also results in a shorter stance time with each footstrike. Therefore, it is expected that vertical and mediolateral impulses will also be reduced.

While habitual BF runners usually land with a midfoot strike (MFS) or FFS pattern,[3] novice BF runners may persist with an RFS pattern and experience higher loading rates than when shod.[3,16] It has been theorized that an RFS is uncomfortable or painful when running BF, thus encouraging runners to naturally transition to an FFS. However, the length of time it takes novice BF runners for this transition is unknown. In a recent study, 20 of 30 novice BF runners immediately transitioned to an FFS without instruction.[19] Despite this transition, two of 20 runners maintained high loading rates. Therefore, providing feedback and instruction early in the process may assist in reducing impacts and loading rates when first learning to transition to BF running.

The purpose of this study was to determine changes in loading parameters when habitually shod runners who exhibit