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Original research

Shoe cushioning reduces impact and muscle activation during landings from unexpected, but not self-initiated, drops

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ABSTRACT

Objectives: To date, few rigorous scientific studies have been conducted to understand the impact mechanics and muscle activation characteristics of different landing tasks and the influence of shoe properties. The aim of this study was to examine the effects of shoe cushioning on impact biomechanics and muscular responses during drop landings.
Design: A single-blinded and randomized design.
Methods: Twelve male collegiate basketball players performed bipedal landings from self-initiated and unexpected drops (SIDL and UDL) from a 60-cm height wearing highly-cushioned basketball shoes (Bball) and less cushioned control shoes (CC). Sagittal plane kinematics, ground reaction forces (GRF), accelerations of the shoe heel-cup, and electromyography (EMG) of the tibialis anterior (TA), lateral gastrocnemius, rectus femoris (RF), vastus lateralis (VL), and biceps femoris (BF) were collected simultaneously.
Results: In SIDL, no significant differences were observed in peak vertical GRF, peak heel acceleration, or EMG amplitude (root mean square, EMG_{RMS}) for all muscles between the two shoe conditions. In UDL, however, both peak vertical GRF and heel acceleration were significantly lower in Bball compared to CC. Furthermore, the EMG_{RMS} of TA, RF, VL, and BF muscles showed a significant decrease in Bball compared to CC within the 50 ms after contact.
Conclusions: These observations suggest that shoe cushioning may make only a limited contribution to reducing landing impact forces provided that neuromuscular adjustments occur properly, as in SIDL. However, in the situation where pre-planned neuromuscular activity is reduced or absent, as in UDL, wearing a highly-cushioned shoe decreases peak impact and muscle activation in the 50 ms after ground contact.

1. Introduction

Lower extremity injuries are closely associated with impact upon ground contact, as repetitive and excessive loading induces both acute trauma, i.e., sprain, muscle-tendon strain, fracture,[1,2] and overuse damages, i.e., stress fracture, patellofemoral pain syndrome, and internal derangement of knee joint.[3,4] Many injuries occur during landing activities, which generate peak vertical ground reaction forces (GRF) as high as 3.5–6 times body weight (BW).[5] Factors known to affect impact load include landing speed, anticipatory neuromuscular activity, and shoe/surface characteristics.[6,7] To reduce the risk of impact-related injuries in athletic activities, footwear manufacturers have focused on designing shoes that can reduce impact loading, and thus the concept of "cushioning" has been widely used since the 1970s.

Each shoe/contact speed combination provides a specific impact input into the corresponding lower extremity muscles. Boyer and Nigg showed that different combinations of landing speed and shoe-midsole material lead to different GRF loading rates, and that shoe midsole properties have a greater effect on loading rate and peak impact magnitude at higher contact speeds.[8] It has also been shown that reduced impact loading and longer times to peak impact force were achieved by wearing shoes with softer midsoles.[9] However, a number of studies have reported that the peak impact characteristics were relatively insensitive to changes in shoe cushioning during touchdown phase in weight bearing

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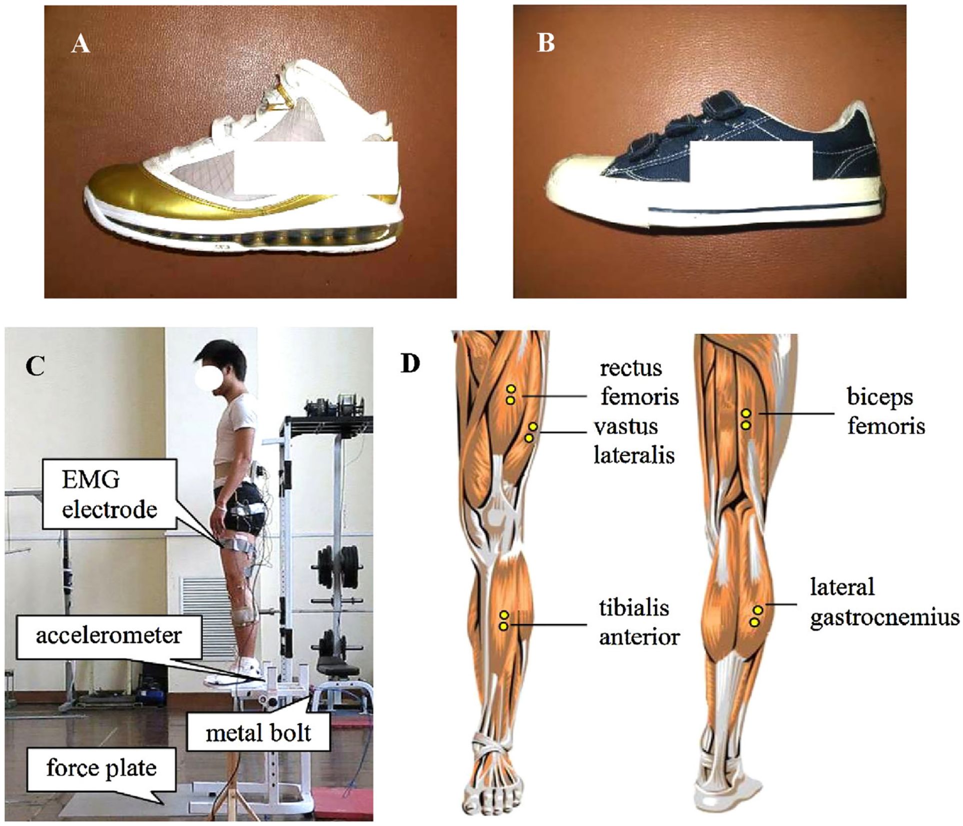

Fig. 1. Basketball shoe (A); control shoe (B); experimental setup (C); placements of surface electrodes (D).

activities.[10,11] The inconsistency among studies may be attributed to lower extremity muscle adaptations that lead to the differences in the initial foot and leg angle, the touchdown velocity, and leg stiffness.[12]

Muscle activation shortly before and after ground contact is associated with preparing for and responding to the impact, and thus executing the movement task, e.g., running or landing.[13,14] The relationship between impact force and muscle responses has been studied using both experiments and modeling over the past decade.[7,15] The impact can be regarded as an input signal into the human locomotor system, and it initiates lower extremity soft tissue vibrations. The central nervous system responds to the signal by activating corresponding muscle groups, and the musculoskeletal system controls the activation level to avoid a resonance situation.[13] This type of neuromuscular adaptation has been shown to minimize vibrations and affect leg posture during ground contact.[16]

The drop jump, regarded as "an active landing from a self-initiated drop" (self-initiated drop landing, SIDL), is an effective training modality to develop explosive/reactive strength, and it is underpinned by fast stretch shortening cycle (<250 ms ground contact) characteristics.[5] It has been used frequently as a screening tool, and is characterized by intentional muscle pre-activation and/or centrally pre-programmed motor control to attenuate landing shocks and prevent joint collapse after touchdown.[17] Contrarily, "a landing from an unexpected drop" (unexpected drop landing, UDL), which is mostly unanticipated, has been proposed to generate significant and potentially detrimental alterations to impact absorption and lower extremity configuration during dynamic sports postures.[18] To date, few rigorous scientific studies have been conducted to understand the impact mechanics and muscle activation characteristics of these two landing tasks and the influence of shoe properties. Furthermore, it is noteworthy that a pre-planned task such as the traditional drop jump is a relatively poor screening tool and injury predictor,[19] and cannot fully mimic the unexpected and chaotic situations in real sports activities. Thus, alternative screening tools that induce a degree of unpredictability into the task may be more appropriate.

The purpose of this study, therefore, was to investigate the effects of different footwear on impact, muscle activity (pre- and post-activation), and their possible interactions during bipedal landings from self-initiated and unexpected drops. It was hypothesized that highly-cushioned shoes would decrease the magnitude of impacts and affect the amplitude of electromyography (EMG) activity during self-initiated and unexpected drop landings.

2. Methods

Twelve male collegiate basketball players (age: 23.7 ± 2.7 years, height: 178.3 ± 2.5 cm, body mass: 70.1 ± 4.6 kg) were recruited for this experiment. All participants had experienced plyometric and resistance training for 5–6 years. None of them had known musculoskeletal injuries of the lower extremity within the past six months. A two-tailed *t*-test was executed via the G*Power 3.1 software to determine whether a sample size of 12 was sufficient to minimize the probability of type II error for all the variables (p = 80% at $\alpha = 0.05$).[20] Each participant signed an informed consent prior to the study. The project was approved by the ethics committee of Shanghai University of Sport.

Two types of shoe that differed in their cushioning properties were adopted in the study (Fig. 1A/B). One was a basketball shoe (Bball) incorporating a viscoelastic midsole and a full-length cushioning unit in both the forefoot and heel. Specifically, the midsole was 8–10 mm thick and made of soft ethylene vinyl acetate foam (Shore A 20-30). The other was a less cushioned shoe (control condition, CC) (Shanghong Shoes Co., Ltd., ClassyVast) comprising a