EFFECTS OF BASKETBALL SHOE ON IMPACT FORCES AND SOFT TISSUE VIBRATIONS DURING DROP JUMP AND UNEXPECTED DROP LANDING

Weijie Fuand Yu Liu

School of Kinesiology, Shanghai University of Sport, Shanghai, China

The purpose of this study was to explore the effects of footwear on impact forces and soft tissue vibrations during drop jump and unexpected drop landings. Twelve male basketball players were instructed to wear two types of shoes to execute double-leg landings in each of 6 testing conditions, i.e. 2 landing styles × 3 landing heights, from a customized platform. Joint kinematics, ground reaction force, and soft tissue vibrations of the leg were collected simultaneously. The results indicated that a shoe intervention did not influence the characteristics of the impact force and soft tissue vibrations during active drop jumps. Contrarily, for the unexpected drop landings, the basketball shoe with strong cushioning properties can substantially reduced the peak impact forces as well as decreased the impact frequency and minimized the peak transmissibility.

KEY WORDS: footwear, impact forces, soft tissue vibrations, landings.

INTRODUCTION: In recent years, a series of new paradigms concerning the role of impact forces have been provided based on both experiments and modeling(Boyer & Nigg, 2007a; Nigg & Wakeling, 2001). The impact forces are considered as an input signal into the human locomotor system; meanwhile the soft-tissue packages of the human body are regarded as oscillating masses(Nigg & Wakeling, 2001; Pain & Challis, 2006). The impacts generate a shock wave and initiate soft tissue vibrations of the lower extremity. Since the resonance oscillations should be expected to occur if the frequency of the input signal is close to the natural frequencies of the lower extremity soft-tissue packages, the musculoskeletal system would sequentially respond to the input signal by changing the mechanical properties of soft tissue in order to avoid the resonance situation (Boyer & Nigg, 2007b). This neuromuscular adaptation is proposed to minimize vibrations and further prevent sports-related injuries (Boyer & Nigg, 2006).

With respect to footwear, different shoe conditions can potentially modify the mechanical input into the musculoskeletal system resulting from a given impact situation. A study by Boyer and Nigg (2007a) showed that at a given wall impact speed for specific shoe-midsole material combinations, changes in peak impact forces, loading rates, and frequency of the wall reaction forces were induced. Similarly, Lafortune et al. (1996) reported the mean power frequency of both force and shank shock generally increased with harder impacting interfaces during human pendulum tests.

Based on the above observations, it is logical to assume a close relationship between variations of shoe properties and changes in impact force characteristic for a quasi-static situation. Questions, however, still remain unanswered as to whether different shoe / speed (height) combinations also influence the input signal pattern and further alter the soft tissue vibrations (output) in more strenuous landing tasks. The purpose of this study was therefore to explore the effects of footwear on impact forces, soft tissue vibrations, and their possible interactions during active landings (drop jump, DJ) and unexpected drop landings (passive landing, PL) from different drop heights.

METHODS: Twelve male basketball players (23.7 ±2.7 y, 178.3 ±2.5 cm, 70.1±4.6 kg) were recruited for this experiment. All participants had 5-6 years of experience in basketball events and none of them had known musculoskeletal injuries of the lower extremity half a year. Two shoe conditions that differed in the cushioning properties were adopted in the study. One was a basketball shoe (Bball) featured by a maximized cushioning pylon midsole and a fulllength cushioning unit. The other was a minimally cushioned control condition shoe (CC) consisting a rubber outsole and a thin foam insole but no midsole.

Landing measurement consisted of a drop jump (DJ) and an unexpected drop landing (passive landing, PL) from heights of 30, 45, and 60 cm. For the PL task, participants were asked to stand on the landing platform. The base of platform was then dropped manually by pulling a metal bolt from its slot to initiate the sudden drop landing movement. Two 90 cm length × 60 cm width force-plates (9287B, Kistler Corporation, Switzerland), embedded into the floor, were employed to capture ground reaction force (GRF) data at a sampling rate of 1200 Hz. Vibrations of the quadriceps femoris and hamstrings were simultaneously collected using two biaxial accelerometers (Biovision Corp., Wehrheim, Germany) via the data acquisition system and DASYLab software (8.0, DATALOG GmbH, Mönchengladbach, Germany) at a sampling rate of 1200 Hz. Twenty-eight retroreflective markers (14.0 mm diameter) comprising the plug-in gait marker set were attached to the lower limb to define hip, knee, and ankle joints. Sagittal kinematic data of the dominant lower extremity were monitored at a sampling rate of 120 Hz with eight high-speed infrared cameras (Vicon MX, Oxford Metrics, UK) during different landing activities.

The main variables discussed in this study for input signal were peak GRF (F_{Zmax}), peak loading rate (G_{Zmax}) and input frequency (f_{GRF}) (Boyer & Nigg, 2007b). To determine the changes of vibration characteristics of a mechanical system, i.e. soft-tissue compartments in this study, a transfer function of frequency (referred to as the transmissibility) was used with a modification of the algorithm used in previous research (Boyer & Nigg, 2006). The resonance frequency of the vibrating system (f_R) and the peak magnitude of the transmissibility (H_{max}) were derived from the frequency response function.

A 2 × 3 two-way (shoe × height) repeated measures ANOVA was executed to determine the effects of the shoes and the drop heights on impact forces and soft tissue responses. Tukey post hoc tests were used to determine individual significant differences (13.0, SPSS Inc., Chicago, IL, U.S.A.). The significance level was set at α=0.05.

RESULTS: No significant differences in the ankle, knee, and hip joint range of motion were found between the Bball and CC groups during landing phases. However, there was a significant main effect associated with the height change for all three joints in both DJ and PL.

No significant interaction was observed between the shoe groups and the landing height. The two-way ANOVAs showed no main effects of shoe for the peak F_Z during DJ at all heights (Figure 1a). In contrast, the post hoc comparisons showed that the peak impact force of wearing basketball shoe was significantly lower than that of the CC group in PL at 30 cm, 45 cm, and 60 cm heights, respectively. As expected, F_{Zmax} increased continuously with landing height increasing from 30 to 45 cm and from 45 to 60 cm in either DJ or PL. Similarly, the G_{Zmax}, which is determined by the maximum slope of adjacent points of vertical GRF, did not change between shoe groups in DJ. However, the Bball group showed a significantly lower G_{Zmax} compared to CC across all three heights in the PL task (Figure 1b, p <0.05).

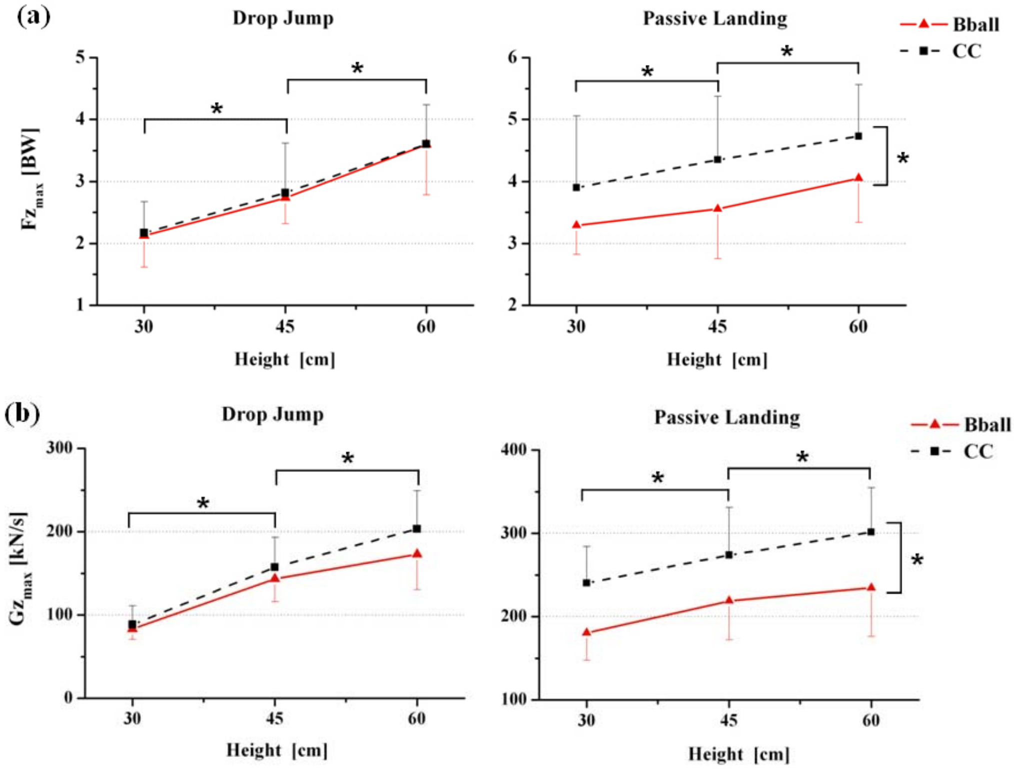

Figure 1: The comparison of peak ground reaction forces, F_{Zmax} (a), and peak loading rates, G_{Zmax} (b), between basketball shoe (Bball) and control shoe (CC) groups during drop jumps and passive landing activities at three different heights. * indicates significant differences. Right-pointing brackets indicate significant differences between groups at all levels of height.

On average there was no significant shoe effect and height effect on the input frequency during the impact phase of DJ. On the contrary, for the sudden drop landing, the effect of basketball shoe on the input signal was a significant decrease in f_{GRF} at 45 cm and 60 cm.
For the soft tissue resonance frequency, no significant differences were observed between the shoe conditions for quadriceps and hamstrings in both DJ and PL (Figure 2a). On average there was no significant shoe effect on the H_{max} during the impact phase of DJ. In contrast, the H_{max} in Bball was significantly lower compared to CC for both the quadriceps and hamstrings during passive landings from 60 cm height (Figure 2b).

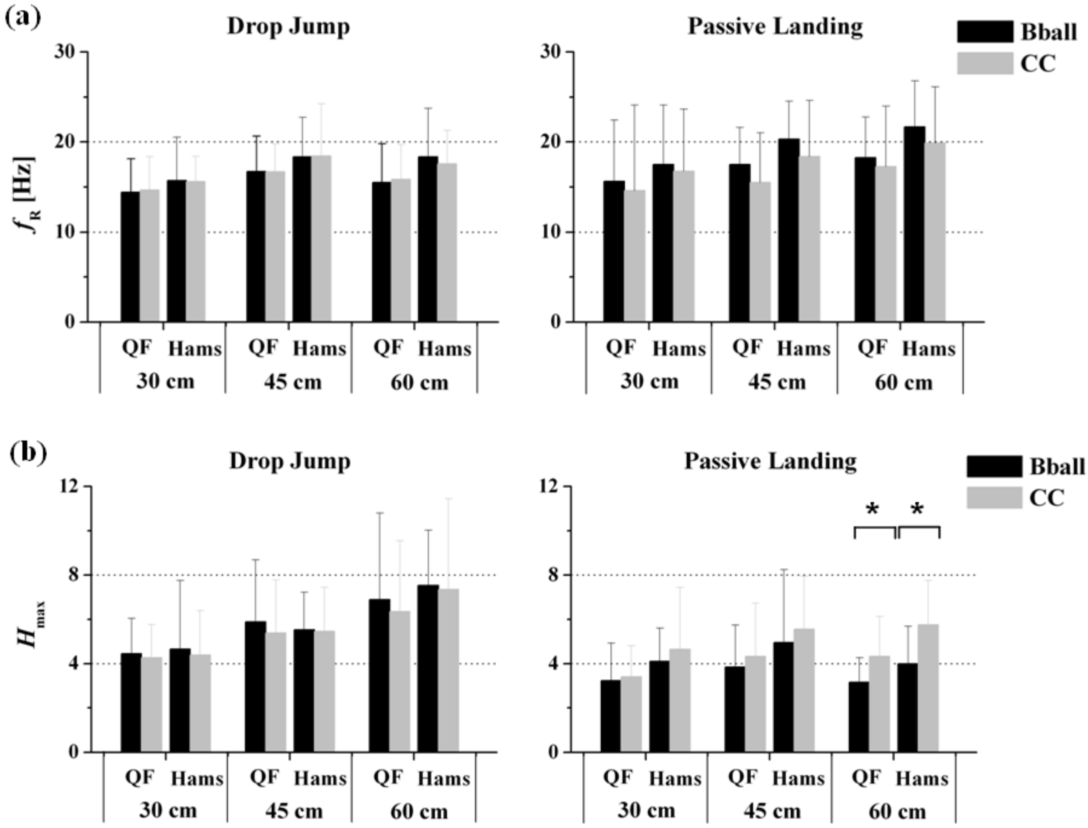

Figure 2: The comparison of main resonance frequencies, f_R (a), and peak magnitude of the transmissibility, H_{max} (b), of the quadriceps femoris (QF) and hamstrings (Hams) muscles between basketball shoe (Bball) and control shoe (CC) groups during drop jumps and passive landings at three different heights.

DISCUSSION: During active landing, the intervention of basketball shoe did not significantly change the characteristics of impact force as an input signal as well as the resonance frequency and peak transmissibility. In these active movements (drop jump, running, etc…) the musculoskeletal adjustments / adaptations in the lower extremity, e.g. the EMG activation (Moritz & Farley, 2004), leg stiffness (Ferris, Louie, & Farley, 1998), or landing kinematics (Hardin, van den Bogert, & Hamill, 2004), can properly occur and partially eliminate the effect of a shoe / surface intervention on the magnitude and frequency characteristics of impact forces. These further imply movement control strategies are more important in protecting the locomotor system against impact loading than shoe interventions in those actions (Denoth, 1986).

Unlike DJs, an anticipatory landing task, subjects should have little warning and therefore be much less properly prepared during the unexpected drop landings. The unexpected position change, mainly due to the inadequate postural control in the lower extremity, can reduce muscle involvement and cause an inadequate adaptation strategy of neuromuscular system in response to different impact and input signals to the human body(Gerritsen, van den Bogert, & Nigg, 1995; Hardin et al., 2004). Consequently, the basketball shoe adopted in the present study plays an important role, similar to those of the movement control strategies using in drop jumps, in reducing the magnitude of both F_{Zmax} and G_{Zmax}, deceasing input frequency, and minimizing the magnitude of peak transmissibility within tissues during the impact phase of unexpected landings. In summary, our findings provide preliminary evidence suggesting that 1) the shoe intervention did not influence the characteristics of the impact force and soft tissue vibrations during active drop jumps; 2) if the neuromuscular system fails to prepare properly for an impact during landing, the shoe intervention may be an effective method for reducing soft tissue vibrations through minimizing impact force and resonant oscillations.

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