Human Movement Science 32 (2013) 1299–1309

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Do knee concentric and eccentric strength and sagittal-plane knee joint biomechanics differ between jumpers and non-jumpers in landing?

Xie Wu [a], Songning Zhang [a,b,*], Yu Liu [a], Dongbin Zhang [a], Bin Xie [a]

[a] *Sport Performance Research Center, Shanghai University of Sport, Shanghai 200438, China*
[b] *Biomechanics/Sports Medicine Lab, Department of Kinesiology Recreation & Sport Studies, The University of Tennessee, 1914 Andy Holt Avenue, Knoxville, TN 37996-2700, USA*

A R T I C L E   I N F O

Article history:
Available online 21 September 2013

PsycINFO classification:
3380

Keywords:
Landing
Eccentric strength
Knee
Isokinetic
Joint moment
Impact

A B S T R A C T

The purpose of this study was to investigate the differences of knee concentric and eccentric strength and impact related knee biomechanics between jumpers and non-jumpers during step-off landing tasks. Ten male college swimming athletes (non-jumpers) and 10 track and volleyball athletes (jumpers) were recruited to participate in two test sessions: a muscle strength testing session of concentric and eccentric extension for dominant knee joint at 60 °/s and 180 °/s and a landing testing session. The participants performed five trials of step-off landing in each of four conditions: soft and stiff landing from 0.4 m and 0.6 m landing heights. The three-dimensional kinematics and ground reaction force were recorded simultaneously during step-off landing conditions. The results showed that the jumpers had significantly greater peak knee eccentric extension and concentric flexion torques compared to the non-jumpers. No significant group effects were found for peak vertical ground reaction force and knee range of motion during landing. The jumpers had significantly greater knee contact flexion angle, maximum knee flexion angle and initial knee extension moment compared to the non-jumpers. These results suggest that these athletes adopted a favorable impact attenuation strategy that is related to the greater knee eccentric muscle strength and training.

* Corresponding author. Tel.: +1 865 974 4716; fax: +1 865 974 8981.
E-mail address: szhang@utk.edu (S. Zhang).

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http://dx.doi.org/10.1016/j.humov.2013.03.008

1. Introduction

Due to high impact forces experienced by the body, landing is a common movement task used in investigating impact attenuation and impact related lower extremity injury mechanisms (Decker, Torry, Noonan, Riviere, & Sterett, 2002; Decker, Torry, Wyland, Sterett, & Richard Steadman, 2003; Devita & Skelly, 1992; McLean et al., 2007; McNitt-Gray, 1991, 1993; Zhang, Bates, & Dufek, 2000). It has been demonstrated that impact forces in landing increased with the lower extremity stiffness (Self & Paine, 2001; Zhang et al., 2000) and landing height (McNitt-Gray, 1993). Skeletal muscles are actively involved in attenuating impact force during human movements (Derrick, Hamill, & Caldwell, 1998; Lafortune, Lake, & Hennig, 1996, Zhang, Derrick, Evans, & Yu, 2008). The knee extensors, in particular, play an important role in impact force attenuation during landing activities (Decker et al., 2003; Zhang et al., 2000). Furthermore, weaker knee strength in females has been related to a stiffer landing style compared to males which may have implications in non-contact ACL injury (Lephart, Ferris, Riemann, Myers, & Fu, 2002).

Although it is well known that landing performance is controlled by eccentric contractions of lower extremity extensors during the landing phase, previous research studies on muscles strengths related to landing were mostly conducted in a concentric or isometric mode (Barber-Westin, Noyes, & Galloway, 2006; Beutler, de la Motte, Marshall, Padua, & Boden, 2009; Hewett, Myer, & Zazulak, 2008; Lephart et al., 2002; Shultz, Nguyen, Leonard, & Schmitz, 2009). Bennett et al. (2008) conducted the only study in literature investigating the relationship between lower extremity eccentric strength and anterior tibia shear force during jump landing. To our knowledge, no other studies have examined the relationship between the knee joint eccentric strength and impact related variables in landing.

Hewett et al. (1999, 1996) suggested that plyometric training (i.e., eccentric training) incorporating dynamic stabilization exercises could reduce impact forces in landing and incidence of knee injury in female athletes. Beutler et al. (2009) evaluated the isometric lower extremity muscle strength and jump-landing performance using a Landing Error Scoring System on 2,753 military cadets, and concluded that muscle strength may not be related to improved landing techniques. Bennett et al. (2008) also suggested that the eccentric quadriceps and concentric hamstring strengths and the quadriceps/hamstring ratio were not indicative of sagittal-plane knee dynamic loading during a jump landing task as it is unlikely that landing requires maximal effort. However, the landing height was only 30 cm. Few studies in the literature have investigated the landing strategies for athletes with different eccentric training experiences. McNitt-Gray (1991, 1993) examined kinematic and kinetic characteristics of different landing strategies exhibited by gymnasts and recreational athletes and found no significant differences on knee-related variables as well as the impact peak force during landing between two groups.

In most of previous landing biomechanics studies, participants were asked to control maximum knee flexion (Devita & Skelly, 1992; Zhang et al., 2000), ankle dorsiflexion (Cortes et al., 2007; Self & Paine, 2001), or select their own landing styles. It has been demonstrated that impact force in landing is very sensitive to maximum knee flexion (Dufek & Bates, 1991; Zhang et al., 2000). A self-selected landing strategy has merits as they represent a realistic and individual performance style. However, it may also introduce an additional source of variability that could influence impact forces and their attenuation. The self-selected landing strategy could also be influenced by the individuals' perceptions of the strategy, which may or may not be a "suitable" strategy in impact attenuation during landing. Currently, it is unknown if knee eccentric muscle strength would influence impact attenuation and related biomechanical variables during landing when the landing strategy (i.e., maximum knee flexion) is controlled.

Therefore, the purpose of this study was to investigate the differences in knee eccentric strength, impact forces, and impact related knee biomechanics between jumpers and non-jumpers during step-off landing with prescribed soft and stiff landing styles from two different landing heights. We hypothesized jumpers would have a similar eccentric knee strength and peak impact force in both soft and stiff landings compared to non-jumpers.