Human Movement Science 33 (2014) 263–272

Contents lists available at ScienceDirect

Human Movement Science

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

Leg stiffness: Comparison between unilateral and bilateral hopping tasks

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ARTICLE INFO

Article history:
Available online 26 November 2013

PsycINFO classification:
2330
2260
3720

Keywords:
Laterality
Hopping test
Leg dominance
Vertical stiffness
Spring-mass

ABSTRACT

Leg stiffness is a predictor of athletic performance and injury and typically evaluated during bilateral hopping. The contribution of each limb to bilateral leg stiffness, however, is not well understood. This study investigated leg stiffness during unilateral and bilateral hopping to address the following research questions: (1) does the magnitude and variability of leg stiffness differ between dominant and non-dominant legs? (2) Does unilateral leg stiffness differ from bilateral leg stiffness? and (3) Is bilateral leg stiffness determined by unilateral leg stiffness? Thirty-two physically active males performed repeated hopping tests on a force platform for each of the three conditions: bilateral hopping, unilateral hopping on the dominant leg, and unilateral hopping on the non-dominant leg. Leg stiffness was estimated as the ratio of the peak vertical force and the maximum displacement using a simple 1-D mass-spring model. Neither the magnitude nor variability of leg stiffness differed between dominant and non-dominant limbs. Unilateral leg stiffness was 24% lower than bilateral stiffness and showed less variability between consecutive hops and subjects. Unilateral leg stiffness explained 76% of the variance in bilateral leg stiffness. We conclude that leg stiffness estimates during unilateral hopping are preferable for intervention studies because of their low variability.

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http://dx.doi.org/10.1016/j.humov.2013.08.009

1. Introduction

Leg stiffness is an important parameter in human biomechanics research because of its proposed influence on performance and injury (see review by Butler, Crowell, & Davis, 2003). For instance, leg stiffness has been shown to correlate positively with performance in high intensity sports, such as sprinting and countermovement jumping (Bret, Rahmani, Dufour, Messonnier, & Lacour, 2002; Chelly & Denis, 2001; Durand, Ripamonti, Beaune, & Rahmani, 2010) and has also been shown to be higher in power-trained athletes compared to endurance-trained athletes (Hobara et al., 2008). However, high leg stiffness is also thought to increase the risk of bony injury in high intensity sport, while low leg stiffness is thought to raise the risk of soft tissue damage (Butler et al., 2003; Granata, Padua, & Wilson, 2002; Williams, Davis, Scholz, Hamill, & Buchanan, 2004; Williams, McClay, & Hamill, 2001). Such findings, however, are largely based on a one-dimensional spring-mass model of a bilateral hopping task, in which a lumped mass representing the body is attached to a single, in-plane weightless spring representing combined leg stiffness (Fig. 1). Although these studies focused mainly on bilateral hopping, presumably because of its simplicity and high reliability (McLachlan, Murphy, Watsford, & Rees, 2006), they do not allow for an evaluation of the stiffness of each limb. Recent research in which unilateral hopping was evaluated have indicated that soft tissue injuries may be related to both high and low leg stiffness (Maquirriain, 2012; Watsford et al., 2010). In a prospective study of professional footballers, Watsford et al. (2010) reported that footballers who sustained a hamstring injury over the course of the season had higher preseason leg stiffness in the affected limb (5%) than footballers who did not sustain an injury (Watsford et al., 2010). In contrast, Maquirriain (2012) observed that athletes with unilateral Achilles tendinopathy had lower leg stiffness in the affected leg when compared to the contralateral limb.

While estimation of combined limb stiffness during a bilateral hopping task is widely used, it based on two unverified assumptions (Nikooyan & Zadpoor, 2011). The first assumption is that leg stiffness determined during bilateral hopping provides insight into leg stiffness during unilateral hopping. It is possible that individuals may adopt a different movement strategy during unilateral hopping compared to bilateral hopping, due to the higher loading of the limb in the unilateral task. The second inherent assumption is that both legs have similar leg stiffness and hence contribute equally to overall leg stiffness values (Fig. 1b). Such an assumption, however, fails to consider the potential effects of limb dominance, laterality and asymmetric limb loading reported in able-bodied walking (Sadeghi, Allard, Prince, & Labelle, 2000) and drop landing tasks (Niu, Wang, He, Fan, & Zhao, 2011).

The aim of this study, therefore, was to evaluate leg stiffness during unilateral and bilateral hopping tasks in a cohort of healthy young males. The following three research questions were specifically

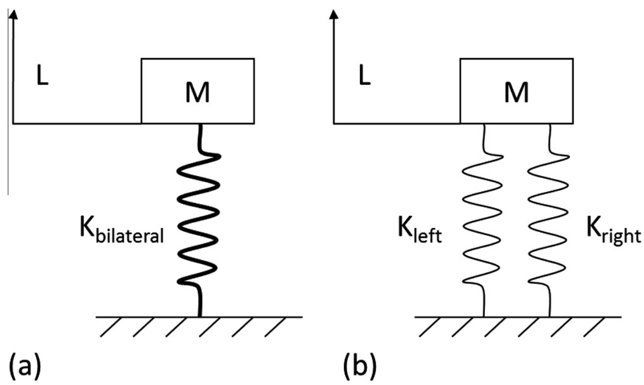

Fig. 1. Schematic representation of combined limb stiffness ($K_{bilateral}$) determined using a one-dimensional spring-mass model of a bilateral hopping task (a) The model assumes that combined limb stiffness reflects the sum of the stiffness ($K_{left} + K_{right}$) of each limb (b).