Physical Therapy in Sport 22 (2016) 54–60

Contents lists available at ScienceDirect

Physical Therapy in Sport

journal homepage: www.elsevier.com/ptsp

Original research

Sagittal plane kinematic differences between dominant and non-dominant legs in unilateral and bilateral jump landings

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ARTICLE INFO

Article history:
Received 12 August 2015
Received in revised form
19 March 2016
Accepted 1 April 2016

Keywords:
Limb dominance
Asymmetry
Lower extremity
Symmetry

ABSTRACT

Context: In both research and clinical settings there is an assumption of symmetry between limbs in landing. However, development of a preferred limb side is a natural occurrence. It is not well established how limb dominance affects landing mechanics in a unilateral or bilateral landing.
Objective: To investigate sagittal plane mechanics between dominant and non-dominant legs in both unilateral and a bilateral landing tasks.
Design: Cross-sectional study.
Setting: Laboratory environment.
Participants: 148 male athletes.
Main outcome measures: Sagittal plane kinematics (hip, knee, and ankle flexion) at initial contact and maximum knee flexion, and total excursion of the movement.
Results: No significant differences were found between limbs in the unilateral landing. Knee flexion ($p = 0.02$) and hip flexion ($p = 0.00$) were significantly different between dominant and non-dominant limbs at initial contact in the bilateral landing. Knee flexion total excursion ($p = 0.04$) and hip flexion total excursion ($p = 0.03$) in the bilateral landing were also significantly different between limbs.
Conclusions: Lower limb symmetry was observed for the unilateral landing. Minimal, yet significant, asymmetries (less than 2°) were present during the bilateral landing. This finding justifies the continued use of the dominant limb in research and clinical settings.

1. Introduction

Previous research investigating landings, both unilateral and bilateral, have assumed symmetry between limbs (McElveen, Riemann, & Davies, 2010; Pappas, Hagins, Sheikhzadeh, Nordin, & Rose, 2007; Schot, Bates, & Dufek, 1994). These landings are also used for the screening of injury risk and return-to-play protocols. In clinical settings, therapists assess patients' contralateral limb range of motion (Macedo & Magee, 2008) and landing mechanics (Ernst, Saliba, Diduch, Hurwitz, & Ball, 2000), with the goal of identifying and correcting asymmetries between legs. However, the development of overuse and acute injuries in one limb contradicts the assumption of symmetry. In fact, lower extremity asymmetry is an important factor because it can lead to overloading of one limb (Schot et al., 1994) and contributes to the development of unilateral lower limb injuries such as ACL injury (Griffin et al., 2000; Laughlin, Weinhandl, Kernozek, Cobb, Keenan, & O'Connor, 2011; Mihata, Beutler, & Boden, 2006; Podraza & White, 2010), patellar tendinopathy (Bisseling, Hof, Bredeweg, Zwerver, & Mulder, 2007; Malliaras, Cook, & Kent, 2006), patellofemoral pain (Boling, Padua, Marshall, Guskiewicz, Pyne, & Beutler, 2009), chronic ankle instability (Terada, Pietrosimone, & Gribble, 2014), and ankle sprains (Hadzic, Sattler, Topole, Jarnovic, Burger, & Dervisevic, 2009).

While an injury can certainly cause side to side differences in lower extremities, asymmetries occur in healthy individuals as well. Development of a preferred, or dominant, limb is a natural occurrence (Gabbard & Hart, 1996; Singh, 1970). The development of lower extremity limb dominance in an athlete can stem from strength differences (Brown, Brughelli, & Bridgeman, 2015; Newton et al., 2006; Zvijac, Toriscelli, Merrick, Papp, & Kiebzak, 2014),

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http://dx.doi.org/10.1016/j.ptsp.2016.04.001
1466-853X/

incomplete or improper recovery from an injury (Doherty et al., 2014; Ithurburn, Paterno, Ford, Hewett, & Schmitt, 2015), or repetitive use of a limb for a task (Iga, George, Lees, & Reilly, 2009). Research remains inconclusive to the effect on performance, linking asymmetries in lower-limb characteristics to both increased performance (Bell, Sanfilippo, Binkley, & Heiderscheit, 2014; Ruas, Minozzo, Pinto, Brown, & Pinto, 2015) and decreased performance (Hart, Nimphius, Spiteri, & Newton, 2014). Differences in neuromuscular strength, flexibility, and coordination between contralateral limbs have been shown to increase injury risk (Hewett, Lindenfeld, Riccobene, & Noyes, 1999; Knapik, Bauman, Jones, Harris, & Vaughan, 1991). Both the dominant and non-dominant limbs are at risk for injury: the dominant limb because of the greater dependence and increased loading and the non-dominant limb because of its inability to maintain performance under normal loads (Edwards, Steele, Cook, Purdam, & McGhee, 2012; Ford, Myer, & Hewett, 2003).

Research has identified landing mechanic characteristics in all three planes of motion; however, kinematics in the sagittal plane are primarily responsible for force absorption during landing tasks (Devita & Skelly, 1992; Hoch, Farwell, Gaven, & Weinhandl, 2015). Because of the large contribution to force attenuation during a landing as well as the relative ease of measurement from visibly large excursions during a landing, sagittal plane mechanics have been a primary focus in landing research. Prior sagittal plane research has investigated the differences between unilateral and bilateral landings and found significant differences in landing mechanics of the dominant leg between the two tasks irrespective of gender (Pappas et al., 2007; Reiser, Paulsen, & Maines, 2003; Weinhandl, Joshi, & O'Connor, 2010). Edwards et al. (2012) investigated differences between limbs in a bilateral stop-jump landing. They concluded at initial contact (IC) the non-dominant leg had greater knee flexion compared to the dominant leg (21.1° and 19.3° respectively); likewise, the non-dominant leg had greater hip flexion compared to the dominant limb at both IC (15.8°, 18.6° respectively) and peak vertical force (27.1°, 24.1° respectively). Conversely, in a study addressing differences during unilateral jump tasks, no significant bilateral differences at the ankle, knee, and hip flexion at peak knee flexion were observed (Stephens, Lawson, & Reiser, 2005). There is a lack of knowledge on the effect of limb dominance during different landing tasks and researchers have failed to justify studying only the dominant leg. Further knowledge of limb asymmetry can provide insights into injury risk, rehabilitation, and performance (Bell et al., 2014; Croisier, Forthomme, Namurois, Vanderthommen, & Crielaard, 2002).

The purpose of this study was to investigate sagittal plane mechanics between dominant and non-dominant legs in a unilateral and a bilateral landing task. We hypothesized there would be differences between the dominant and non-dominant legs in the sagittal plane during the unilateral landing tasks. Furthermore, we hypothesized that the differences between the dominant and non-dominant leg during unilateral landing would exist in the bilateral landing.

2. Methods

2.1. Subjects

This study was approved by the Institutional Review Board of Stony Brook University (Stony Brook, NY). A sample of 148 male athletes were recruited from sports academies, colleges and universities (NCAA Divisions I, II, III), and professional teams (NBA, NFL, FIFA). Males were exclusively used for this study due to the ambiguity in research on females' landings regarding anatomical, neuromuscular, and biomechanical factors (Aerts, Cumps, Verhagen, Verschueren, & Meeusen, 2013). Each subject was administered a waiver and informed consent. After the informed consent process, the subject reported demographic information including: age, limb dominance, sport, experience, and injury history. The lower extremity dominant limb was defined as the preferred leg used to kick a ball, consistent with previous literature (Ford et al., 2003). Researchers measured subjects' body mass and body height. Inclusion criteria was met if the participant currently participated in a sports league, had doctor or physical therapist clearance to participate in sports, and no reported injury in the previous six months. Athletes with a history of knee injury or surgery were excluded from the study.

The mean age of the subjects was 21.7 ± 3.6 years old (range 14.1–37.6 years). The mean height was 190.2 ± 10.9 cm and the mean subject weight was 96.1 ± 18.4 kg. Regarding sport participation, 39% of the subjects played baseball, 30% basketball, 21% football, and the remaining 10% included tennis, soccer, and track and field athletes. Professional athletes made up 58% of the subjects, 30% were college athletes, and 12% were high school sports academy athletes.

2.2. Procedure

After performing his warm-up routine of choice, the subject was instrumented with 45 reflective markers placed on anatomical land marks. The placement of the markers included: bilateral placement on the second metatarsal, posterior calcaneus, lateral and medial malleolus, lateral and medial femoral epicondyle, greater trochanter, anterior and superior iliac spine, lateral tip of the acromion, medial clavicle, upper arm, lateral and medial humeral epicondyle, forearm, radial styloid, and ulnar styloid. Four additional markers were placed on the head (front, back, and right and left sides), as well as on the T2, T8, xyphoid process, right shank, and on the scapula. Markers were affixed to key bony anatomical landmarks using tape and hypoallergenic skin adhesive, and secured with an adhesive overlay.

Three-dimensional (3D) position coordinate data of the reflective markers were collected using an eight camera, 120 Hz Raptor-E motion analysis system (Motion Analysis Corp., Santa Rosa, CA). The global coordinate system was set up so that the positive Z was vertically upward, the X direction was perpendicular to Z with positive X pointing anterior to the athlete, and Y was the cross product of Z and X. One static calibration trial was collected while the subject stood in the middle of the camera's capture volume, facing the positive X direction with the shoulders abducted to 90° and internally rotated 0°, elbows flexed to 90°, and with toes pointed straight. The trial was used to align the subject with the laboratory coordinate system and to define local joint coordinate systems specific to each subject to control for anatomical variation.

Following the static calibration trial, a researcher instructed the subject through three jump landing tests: left-leg and right-leg unilateral drop jump, and bilateral drop jump. The same researcher instructed every subject through the testing in this study to ensure consistent verbal cues. To perform the unilateral drop jump test, subjects stood on a 14 cm box on the respective leg and were instructed to drop on the involved limb on the ground in front of them and subsequently perform a maximum-effort vertical jump using arms to reach above head (Fig. 1). To perform the bilateral drop jump test, subjects stood on a 44.5 cm box on both legs, and were instructed to drop from the box landing simultaneously with feet on the ground in front of them and subsequently performing a maximum-effort vertical jump using arms to reach above head (Fig. 2). The unilateral drop jump tests were performed first, then the subject rested for four to 5 min before completing the bilateral