Physical Therapy in Sport 33 (2018) 133–138

Contents lists available at ScienceDirect

Physical Therapy in Sport

journal homepage: www.elsevier.com/ptsp

Original Research

Vertical drop jump landing depth influences knee kinematics in female recreational athletes

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A R T I C L E I N F O

Article history:
Received 6 February 2018
Received in revised form
5 August 2018
Accepted 6 August 2018

Keywords:
Biomechanics
Knee valgus
Muscle strength
Hip internal rotation

A B S T R A C T

Objectives: To examine whether different vertical drop jump (VDJ) landing depth (small versus deep) and stance width (wide versus narrow) may alter movement biomechanics in female recreational athletes. The purpose was also to identify whether leg muscle strength is a predictive factor for knee control during a VDJ.
Design: Cross-sectional.
Setting: Biomechanics laboratory. Participants: Eighteen women aged between 18 and 30 years.
Main outcome measures: Three VDJ tests were used for biomechanical analysis: 1) small "bounce" jump (BJ), 2) deep "countermovement" jump with wide (CMJW) and 3) narrow foot position (CMJN). Subjects also performed an isometric knee-extension strength test, dichotomized to 'weak' versus 'strong' subjects according to median and quartiles.
Results: There were greater knee valgus angles during landing for both the CMJW and CMJN test compared to the BJ test ($p \leq 0.05$). Differences in knee valgus between weak and strong subjects were significant for the BJ test ($p = 0.044$) but not for any of the other tests.
Conclusions: VDJ landing depth influences knee kinematics in women. Landing depth may therefore be considered when screening athletes using the VDJ test. Also, muscle strength seems to influence the amount of knee valgus angles, but the difference was not statistically significant (except for the BJ test) in this small cohort.

1. Introduction

The vertical drop jump (VDJ) is a commonly used test to assess neuromuscular control and knee loading. The test has been used extensively in research to identify female athletes at risk for anterior cruciate ligament (ACL) injury (Cesar, Tomasevicz, & Burnfield, 2016; Hewett et al., 2005; Myer, Ford, Khoury, Succop, & Hewett, 2010; Zazulak, Hewett, Reeves, Goldberg, & Cholewicki, 2007), in which lower-extremity alignment parameters such as knee valgus angles have been evaluated with both three dimensional (3-D) motion analysis and two dimensional (2-D) video analysis (Munro, Herrington, & Carolan, 2012; Sorenson, Kernozek, Willson, Ragan, & Hove, 2015). Additionally, it has been reported that physiotherapists can identify female athletes with high knee valgus angles in a vertical drop-jump landing using real-time observational screening (Nilstad et al., 2014; Stensrud, Myklebust, Kristianslund, Bahr, & Krosshaug, 2011).

However, the use of specific injury screening – no matter what kind of method – in sports is highly debated (Bahr, 2016; Hewett, 2016). Bahr (Bahr, 2016) recently stated that today there is no study providing support for screening for injury risk. Although the VDJ is a popular screening method the accuracy to identify athletes with high risk could be questioned since existing studies report contradictive results. Hewett et al. (Hewett et al., 2005) noted in a prospective study that female athletes with increased valgus and abduction loads of the knee during a VDJ were at increased risk of ACL injury. Krosshaug et al. (Krosshaug et al., 2016) on the other hand, noted that the VDJ was a poor screening test for ACL injuries in a recent large prospective study of female athletes. It seems, however, that the athletes in these two studies used different drop jump technique. This fact may explain the inconsistent results between studies. In the study by Hewett et al. (Hewett et al., 2005),

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https://doi.org/10.1016/j.ptsp.2018.08.002
1466-853X/© 2018 Published by Elsevier Ltd.

the athletes performed a drop jump in which they seemingly made a deep countermovement after touching the ground, before jumping for maximal height. In contrast, the athletes in the study by Krosshaug et al. (Krosshaug et al., 2016) appear to have performed more of a “bounce” jump type of drop jump, which typically result in relatively small knee and hip angles at joint reversal compared to a “countermovement” drop jump (Marshall & Moran, 2013). To date, no study has compared small “bounce”- versus deep “countermovement” drop jumps when it comes to knee kinematics and kinetics. It could, however, be speculated that the differences in VDJ technique (e.g. landing depth and stance width) may explain the differences in results of the above-mentioned studies regarding the ability of the drop jump test to predict ACL injury risk in athletes. Further, it has previously been recognized that lower extremity muscle strength plays an important role in functional joint stability and that inferior kinematics during dynamic activities may be influenced by impaired muscle strength (Hollman, Hohl, Kraft, Strauss, & Traver, 2013; Nagai, Sell, House, Abt, & Lephart, 2013). However, data on the significance of knee muscle strength on knee valgus motion during VDJ landings is limited. If leg muscle strength is an important factor for safe landing technique, this information could be used in the development of screening programmes.

The aim of the present study was thus firstly to examine whether landing depth (small versus deep) and stance width (wide versus narrow) during a VDJ test may alter movement biomechanics. The purpose was also to identify whether leg muscle strength is a predictive factor for knee control during a VDJ test in women. It was hypothesized that individuals rated as weak, as determined by level of knee extension strength, would display higher valgus angles than individuals rated as strong.

2. Methods

2.1. Study design and participants

The study was performed as a cross-sectional study, adhering to the STROBE statement (“STROBE Statement,” 2007), and took place at the Lundberg Laboratory for Orthopaedic Research at Sahlgrenska University Hospital, Göteborg, Sweden. Eighteen female University students, aged between 18 and 30 years, were recruited for this study (Table 1). The subjects performed three different VDJ tests for biomechanical analysis of neuromuscular control of the knee and an isometric knee-extension test for leg muscle strength determination.

2.2. Procedure

Each test session began with a warm-up, which consisted of 5 min of ergometer cycling at 100 W of resistance. The tests were instructed and supervised by three test leaders with previous experience of biomechanical analysis and physical strength/power testing. The isometric knee extension test and the different drop-jump tests were performed in the same order for all participants, starting with the strength assessment. For all subjects, anthropometric characteristics including height and body weight were measured and reflective markers were affixed to the subject's pelvis and lower extremity in accordance to a previously published kinematic model (Ferrari et al., 2008). The subjects' physical activity level was registered according to the Saltin–Grimby Physical Activity Level Scale (Grimby et al., 2015). Each subject wore their own training shoes.

Table 1
Subject characteristics (n = 18). Values are means and standard deviation (±) except for physical activity level where median (min-max) is reported.

Variable	
Age (years)	23 ± 3
Height (cm)	63 ± 7
Weight (kg)	169 ± 7
Knee extensor muscle strength (N)	510 ± 137
Physical Activity Level	3 (2–4)

2.3. Measurements

2.3.1. Isometric knee extension test

An open kinetic chain test (involving muscles working across a single joint) consisting of a maximal isometric muscle action of the knee extensors was performed using a Kinetic communicator II dynamometer (Chattanooga Group, Inc., Hixson, USA). Peak isometric knee extensor strength (N) of the subjects' dominant leg was measured. The subjects performed three maximal trials and the highest value was documented. High test-retest reliability has previously been reported for this measurement (Intraclass correlation coefficient $[ICC]_{2,1} = 0.93$) (Toonstra & Mattacola, 2013).

2.3.2. Vertical drop jumps

Movement biomechanics was assessed by three different types of VDJs. In this study, the VDJ was performed, with two-legs, as a 1) “bounce” jump with a wide foot stance (BJ), and 2) as a “countermovement” jump, with wide (CMJW) and 3) narrow foot position (CMJN).

1) *BJ*: The subject dropped off a 30-cm box with both legs, positioned 30 cm apart in the starting and landing position and was instructed to as quickly as possible after touching the ground, jump for maximal height.
2) CMJW: The subject dropped off a 30-cm box with both legs, positioned 30 cm apart in the starting (and landing) position and was instructed to make a deep countermovement to a preselected depth (femur below parallel to the floor), after touching the ground, before jumping for maximal height.
3) CMJN: The subject was instructed to drop off a 30-cm box with both legs, using a narrow foot starting (and landing) position (5 cm apart), while again making a deep countermovement with the femur lower below parallel to the floor, after touching the ground, before jumping for maximal height.

A trial was not valid if the subject did not keep either a wide (30 cm) or narrow (5 cm) stance during both the start and landing phase of a particular jump.

A ball was attached to the ceiling at a height that the subject could not reach. In all tests, the subjects perform a maximum vertical jump upon landing, raising both arms trying to touch the ball. In case they did touch the ball, it was elevated to assure best jumping performance. An overhead goal such as a ball has been noted to increase performance during VDJ tests (Ford et al., 2005). The drop CMJ has been shown to be valid and highly reliable tools in assessment of lower extremity function (Silbernagel, Gustavsson, Thomee, & Karlsson, 2006) and the VDJ has been recommended in evaluation of neuromuscular control and knee loading (Mok, Petushek, & Krosshaug, 2016).

2.4. Biomechanical analysis

A biomechanical analysis of the different drop jumps was performed using a three-dimensional motion analysis system (Qualisys Medical AB, Göteborg, Sweden) that consisted of sixteen cameras, passive reflective markers and a computer running a software package (QTM ver 2.13, Qualisys Track manager, Qualsiys