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Relationship of Hip and Trunk Muscle Function with Single Leg Step-Down Performance: Implications for Return to Play Screening and Rehabilitation

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ABSTRACT

Objectives: Evaluate the relationship of hip and trunk muscle function with the Single Leg Step-Down test (SLSD).
Study design: Laboratory study.
Setting: Biomechanics Laboratory.
Participants: 71 healthy participants with no history of anterior cruciate ligament (ACL) or lower extremity injury in the last 3 months completed this study (38 males, 33 females; mean 25.49 ± 0.62 years).
Main outcomes: Hip abduction (HABD), external rotation (HER), and extension (HEXT) peak isometric force were measured. Trunk endurance was measured with plank (PL) and side plank (SPL) tests. SLSD repetitions in 60-s and dynamic knee valgus (VAL) were recorded.
Results: PL, SPL, HABD, HER, and HEXT were positively correlated with SLSD repetitions. PL ($r = 0.598$, $p < 0.001$) was most correlated with SLSD repetitions, and regression demonstrated that PL ($p = 0.001$, $R^2 = 0.469$) was a predictor of SLSD repetitions. VAL trended toward negative correlation with PL and SPL. Sex-specific differences were present, with PL, SPL, HABD, and HER showing stronger relationships with SLSD in females.
Conclusion: Hip and trunk muscle function were positively correlated with SLSD performance, and these relationships were strongest in females. PL predicted performance on the SLSD. Further research is needed to investigate the utility of SLSD as a screening or return-to-play test for lower extremity conditions such as ACL injury and patellofemoral pain.

1. Introduction and background

Lower extremity injuries are an increasingly common occurrence among athletes of all ages. Over three million people in the United States seek emergency room treatment for sports related injuries each year (NEISS Database, 2014). Most of these injuries involve the lower extremity, with the knee being one of the most common sites (Burns & Lowery, 2011; Conn, Annest, & Gilchrist, 2003). These injuries result in significant healthcare and societal costs (Adirim & Cheng, 2003; Conn et al., 2003), especially injuries such as anterior cruciate ligament (ACL) tears. For instance, there are over 200,000 ACL injuries in the United States each year (Maffulli & Osti, 2013); over 175,000 ACL reconstructions (ACL-R) are performed annually at a total cost of over $2 billion (McCullough et al., 2012). Despite recent advances in surgical technique and rehabilitation protocols, the return to play rate of 63–69% after ACL-R is less than ideal (McCullough et al., 2012; Shah, Andrews, Fleisig, McMichael, & Lemak, 2010), with patients at an increased risk for reinjury (Brophy et al., 2012; Hettrich, Dunn, Reinke, Group, & Spindler, 2013; Paterno, Rauh, Schmitt, Ford, & Hewett, 2014) and premature osteoarthritis (Lohmander,

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Englund, Dahl, & Roos, 2007; Maffulli & Osti, 2013). The far-reaching effects of lower extremity injury have led to an increased focus on injury prevention mechanisms, and a call for more objective and cost-effective screening (E. Swart et al., 2014).

A growing body of evidence shows a connection between lower extremity injury with hip and trunk neuromuscular dysfunction (Hollman et al., 2009; Ireland, Willson, Ballantyne, & Davis, 2003; Noehren, Wilson, Miller, & Lattermann, 2013; Powers, 2010; Reiman, Bolgla, & Lorenz, 2009; Stearns & Powers, 2014). For instance, weakness and poor control of the hip muscles in patients with patellofemoral pain has been reported (Ireland et al., 2003; Noehren et al., 2013). Further, Leetun, Ireland, Willson, Ballantyne and Davis (2004) observed that athletes who sustained lower extremity injuries were more likely to have weak hip abduction and external rotation strength, and hip external rotation has been correlated with ACL injury risk (Khayambashi, Ghoddosi, Straub, & Powers, 2016). There is also evidence to suggest that poor neuromuscular control of hip and trunk affects females more than males (Ireland, 1999; Ireland et al., 2003; Leetun et al., 2004). In addition to the hip, trunk strength and poor trunk control have also been implicated as risk factors for lower extremity injury (Abt et al., 2007; Hewett & Myer, 2011; Zazulak, Hewett, Reeves, Goldberg, & Cholewicki, 2007). These findings have led to calls for greater emphasis on core (hip and trunk) strengthening for both prevention of injury and for and rehabilitation after injury (Fredericson & Moore, 2005; Shi et al., 2012). One challenge that remains is how to identify individuals with weak hip and trunk strength who need these prevention and treatment interventions the most. Although the step-down test has been well described (Earl, Monteiro, & Snyder, 2007; Hollman et al., 2009; Lewis, Foch, Luko, Loverro, & Khuu, 2015; Olson, Chebny, Willson, Kernozek, & Straker, 2011), the relationship between single leg step-downs and core muscle function is not well established.

In fact, there have been very few investigations into the relationship between hip strength and single leg step-downs (Colby, Hintermeister, Torry, & Steadman, 1999; Olson et al., 2011; Pollard, Sigward, & Powers, 2010), and only one that examined trunk strength and single leg squats (Stickler, Finley, & Gulgin, 2015). For example, Willson, Ireland, and Davis (2006) demonstrated that females with weak hip external rotation strength had a more medial frontal plane projection angle (FPPA) during step-downs, and Olson et al. (2011) subsequently showed that the FPPA improved (along with hip strength) after a neuromuscular training program. Similarly, Dolak et al. (2011) found patients with patellofemoral pain syndrome were able to perform more step-down repetitions after a hip-strengthening program. However, none of these studies assessed any parameters of trunk muscle function related to step-down performance. In a recent study assessing single leg squats and trunk strength, only coronal plane knee kinematics were used as dependent variables. No parameters of functional performance or measures of participant activity level were assessed (Stickler et al., 2015). Furthermore, previous research has suggested that measuring coronal plane angles on the single-leg step-down may not be sensitive enough to detect lower extremity muscle dysfunction (Lewis et al., 2015).

Thus, the goal of this study was to evaluate the relationship between trunk and hip muscle function (using isometric hip strength and trunk endurance on bridging plank tests as measures of muscle function) and the maximum number of successful repetitions completed on the timed 60-s single leg step-down (SLSD) test. Secondary objectives were to compare hip strength and trunk endurance with coronal plane dynamic knee valgus during step-down, and to determine if the relationships between hip and trunk strength and SLSD differed between men and women. We hypothesized that hip and trunk muscle function would be positively correlated with the number of successful repetitions on the timed SLSD test, and that decreased hip and trunk muscle function would be correlated with increased dynamic knee valgus during performance of a step-down. We also hypothesized that these relationships would be of greater magnitude for female as compared to male participants.

2. Methods

The study protocol was approved by our university's Institutional Review Board. All participants read and signed an informed consent form prior to participation.

2.1. Participants

Seventy-three participants were recruited for this study. Study participants were recruited from a population of convenience via flyers posted on our university medical center campus, and included college students, medical and surgical residents, physical therapists, physical therapy students, and doctoral students. Two participants were excluded from final analysis due to incomplete testing, leaving a total of 71 voluntary participants. There were 33 females and 38 males, ranging from 19 to 45 years of age. All participants were healthy and met the following inclusion criteria: (1) age between 18 and 45 years, (2) currently free of any trunk, hip, or knee injuries within the last three months, and (3) no previous history of injury or surgery that may affect their trunk, hip, or knee function. In order to assess for any differences among baseline activity levels, all participants completed a Tegner Activity Scale that was indicative of their current level of physical activity.

2.2. Procedures

Peak isometric torque (adjusted for mass) was calculated using participants' femur and tibia lengths for the following muscle groups: hip extensors, hip abductors, and hip external rotators. Normalization was performed using the method described by Bazett-Jones, Cobb, Joshi, Cashin, and Earl (2011). For hip extension and hip abduction torque, the following formula was used: torque = [(isometric force in N * (femur length in cm))/mass in kg]. Hip external rotation strength was calculated as follows: torque = [(isometric force in N * (tibia length in cm))/mass in kg]. Trunk endurance was assessed using the plank and side plank tests. All test positions were based on those identified in the literature and were similar to previously described testing (Kline, Johnson, Ireland, & Noehren, 2015; Leetun et al., 2004; Loudon, Wiesner, Goist-Foley, Asjes, & Loudon, 2002; Maeo, Takahashi, Takai, & Kanehisa, 2013; Tong, Wu, & Nie, 2014).

2.3. Strength and functional testing

For the isometric hip strength tests, non-stretchable nylon straps were used to stabilize the participant, and a handheld dynamometer (Lafayette Instruments, Lafayette, IN) was used to record peak isometric force (Fig. 1). This method has been shown in previous trials to be reliable and reproducible (Katoh & Yamasaki, 2009). For each test, one practice and three experimental trials were performed for 5 s, with 15 s of rest between contractions. The dynamometer was re-zeroed between each trial. All measurements were taken on the right leg for uniformity. The average of the three experimental trials was used for calculations.

Hip abduction strength (HABD; Fig. 1A) was tested by positioning the participant in a left side lying position on a flat exam table. A strap was placed over the iliac crest for stability. The participant's pelvis was held in neutral alignment, and soft padding