Physical Therapy in Sport 16 (2015) 317–323

Contents lists available at ScienceDirect

Physical Therapy in Sport

journal homepage: www.elsevier.com/ptsp

Original research

Neuromuscular asymmetries in the lower limbs of elite female youth basketball players and the application of the skillful limb model of comparison

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A R T I C L E I N F O

Article history:
Received 29 September 2014
Received in revised form
24 December 2014
Accepted 24 January 2015

Keywords:
Imbalance(s)
Injury
Return to sport
Rehabilitation

A B S T R A C T

Objectives: Compare the ability of commonly used comparison models to detect neuromuscular asymmetries. A secondary purpose was to determine which neuromuscular task(s) has the greatest sensitivity to identify asymmetries based on the ASI (asymmetry index) calculation.

Methods: Elite female youth basketball players ($N = 29$, age $= 15.7 \pm 1.34$ y) performed the single leg countermovement jump in vertical, horizontal, and lateral directions, the star excursion balance test in the anterior, posteromedial, and posterolateral directions, and the sprint test with change of direction. Paired t-tests compared right and left limbs, the dominant (DL) and non-dominant (NDL) limbs, and the more/less skillful limbs.

Results: The coincident identification between the more skillful leg and the leg subjectively described as the DL was low for all of the tasks performed (35%–52%). There were significant differences between the more and less skillful legs for all tasks, while performances between the right and left limbs and DL and NDL differed significantly for only one task each. The largest ASI detected in this study was found in the vertical single leg countermovement jump (14.11%).

Conclusions: The skillful limb model of comparison may be more useful than other models to detect neuromuscular asymmetries.

1. Introduction

The quantification of neuromuscular deficits between legs is critical in order to identify individuals who may be at risk of injury, to establish when an athlete can return to play following injury, and to optimize strength and conditioning training (Hewit, Cronin, Hume, Zealand, & Sciences, 2012; Overmoyer, 2012). Neuromuscular asymmetry of the lower limbs is associated with injury and can be used as a predictor for future injury or reinjury (Paterno et al., 2010); however, asymmetry in the lower limbs is also a characteristic that may be prevalent in healthy athletes (McElveen, Riemann, & Davies, 2010; Munro & Herrington, 2011). Previous research has examined lower limb imbalances during cutting and pivoting in asymmetrical sports, such as basketball (Theoharopoulos & Tsitskaris, 2000), soccer (Rahnama, Lees, & Bambaecichi, 2005) and volleyball (Lawson, Stephens, Devoe, & Reiser, 2006; Markou & Vagenas, 2006), and in symmetrical

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http://dx.doi.org/10.1016/j.ptsp.2015.01.003
1466-853X/

sports, such as running and cycling (Carpes, Mota, & Faria, 2010). However, conclusions regarding significant strength/power asymmetries between lower limbs are unclear due to conflicting results (Lawson et al., 2006; Newton et al., 2006), and may be attributable to the wide range of sports and neuromuscular capacities tested in the studies.

Differences between limbs with regard to neuromuscular performance, including strength and power, result from multiple factors. These factors include previous anatomical lower limb asymmetries (Fousekis, Tsepis, & Vagenas, 2010), laterality of neural development (development of side dominance) (Miyaguchi & Demura, 2010), previous injury with incomplete recovery (Paterno, Ford, Myer, Heyl, & Hewett, 2007), repetitive asymmetrical sport-specific demands (Newton et al., 2006; Schiltz, Lehance, Maquet, Bury, Crielaard, & Croisier, 2009), professional training age, sport position, and footedness (Fousekis et al., 2010). Lower limb asymmetries in strength, coordination, and postural control, are more common in female athletes than males athletes, and are especially prevalent in adolescents (Myer, Brent, Ford, & Hewett, 2011). The higher incidence of injury in female athletes is associated with neuromuscular factors, including the overall dominance of one leg over the other (Fort-Vanmeerhaeghe & Romero-Rodriguez, 2013).

While lower limb asymmetry can be measured in a variety of ways, most research focuses on strength and power as measured by isokinetic dynamometer (Newton et al., 2006; Rahnama et al., 2005). However, motorized dynamometers are expensive and do not accurately mimic sport-specific movement of the lower limbs. The single-leg vertical jump may provide an alternative solution, as it has demonstrated to be a sensitive functional task to detect power asymmetries between legs (Ceroni, Martin, Delhumeau, & Farpour-Lambert, 2012; Menzel, Chagas, Szmuchrowski, Araujo, de Andrade, & de Jesus, 2012; Stephens, Lawson, DeVoe, & Reiser, 2007). It is important to note that an athlete's performance depends on multiple neuromuscular capacities, including balance, agility, and directional changes. As such, it may be important to assess various components of the neuromuscular system in all three dimensions to best detect relevant lower limb asymmetries (Meylan, Nosaka, Green, & Cronin, 2010). Specifically when assessing jumping tasks, it is important to assess movements in all axes in order to capture a comprehensive snapshot of the athlete's performance (Myer, Schmitt, et al., 2011).

The lower limb asymmetry index (ASI) is commonly used in athletics to quantify neuromuscular deficits between legs (Ceroni et al., 2012; Overmoyer & Reiser, 2013). This index is used to identify athletes at potential risk for injury; the weaker limb is typically predisposed to injury (Hewit, Cronin, Hume, et al., 2012). Current evidence indicates that a difference of 10–15% between legs with performance on isokinetic strength and vertical jump may be the threshold for increased risk of injury (Hewit, Cronin, & Hume, 2012; McElveen et al., 2010; Munro & Herrington, 2011). A more frequently used model of comparison is that of the dominant limb (DL) to the non-dominant limb (NDL). However, training specificity, which is related to adaptations and changes in the nature of leg dominance in sport, makes prediction of leg dominance difficult (Schiltz et al., 2009; Stephens et al., 2007). Different methods of determination of DL and NDL exist. The DL has been defined as the kicking leg (Meylan, McMaster, Cronin, Mohammad, Rogers, & Deklerk, 2009; Theoharopoulos & Tsitskaris, 2000), stronger leg (Impellizzeri, Rampinini, Maffiuletti, & Marcora, 2007), the foot used to initiate stair climbing (Ceroni et al., 2012), the leg used to regain balance after an unexpected perturbation (Hewit, Cronin, & Hume, 2012), or the side with the highest single leg jump height (Ceroni et al., 2012; Stephens et al., 2007). Various authors have observed that many subjects do not jump higher with the self-determined DL than with the self-determined NDL (Schiltz et al., 2009; Stephens et al., 2007). This finding indicates that performance comparisons of DL to NDL may not be useful in detecting differences in neuromuscular capacities.

Quantification of neuromuscular asymmetries in the lower limbs is an important part of identifying young athletes who may be at risk of injury and monitoring the progress of athletes in rehabilitation programs following injury. The primary purpose of this investigation was to compare the ability of commonly used comparison models to detect neuromuscular asymmetries. These comparison models include right to left limb, DL to NDL (i.e., self-determined), and more skilled to less skilled limb (i.e., functional). We hypothesized that measures of subjectively identified limb dominance would provide reduced sensitivity for identification of lower limb asymmetries. A secondary purpose of this investigation was to determine which neuromuscular task(s) has the greatest sensitivity to identify asymmetries based on the ASI calculation. Our corollary hypothesis was that the single leg vertical jump test would have the greatest sensitivity to detect ASI deficits in elite adolescent female basketball players.

2. Methods

The current study employed a cross-sectional design to compare unilateral neuromuscular performance in a group of adolescent female basketball players. The tasks the athletes performed served to measure balance, power, and change of direction. Based on the results of the different performance tasks, the following comparisons were made: the right leg to the left leg; the DL to the NDL; and the more skillful leg to the less skillful leg. Subjective determination of leg dominance was identified by noting which foot the subject used to kick a ball, which foot the subject initiated stair climbing with, and which foot was used to regain balance following a slight, unexpected perturbation. The leg that was described in two or more of the responses was determined to be the dominant one. The more skillful leg was determined to be the leg with higher performance averages on each respective task. In addition, to identify functional imbalances between limbs, we calculated the ASI for each task. Asymmetry index values from the different tasks were also compared to one another to determine the relation between the different unilateral neuromuscular capacities.

2.1. Subjects

Twenty-nine athletes were included in this study. Subjects were eligible for inclusion (see below) if they were elite female basketball players between the ages of 14 and 18. Subjects were excluded if they presented with any injury (overuse or acute) at the time of testing. Table 1 provides subject characteristics. All of the subjects were actively participating in a four-year national professional development program at the time of the study. In addition to a weekend game, subjects had 8–10 training session per week, which lasted approximately 90–120 min per session. Written informed consent and assent were obtained from subjects and their

Table 1
General subjects characteristics (n = 29).

	Mean	SD
Age (y)	15.66	1.34
Weight (kg)	69.69	10.18
Height (m)	1.82	0.07
Sport experience (y)	6.31	1.73
% body fat	14.81	2.55
Right/left lower limb dominance	27/2	
Right/left upper limb dominance	28/1	