



Lower Limb Neuromuscular Asymmetry in Volleyball and Basketball Players

by

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The primary objective of the present study was to evaluate the agreement between the dominant leg (DL) (determined subjectively) and the stronger leg (SL) (determined via a functional test) in a group of basketball and volleyball players. The secondary objective was to calculate lower limb neuromuscular asymmetry when comparing the DL vs the non-dominant leg (NDL) and the SL vs the weaker (WL) leg in the whole group and when differentiating by sex. Seventy-nine male and female volleyball and basketball players (age: 23.7 ± 4.5 years) performed three single-leg vertical countermovement jumps (SLVCJ) on a contact mat. Vertical jump height and an inter-limb asymmetry index (ASI) were determined. Only 32 (40%) of the subjects had a concordance between the perception of their dominant leg and the limb reaching the highest jump height. Using the DL as the discriminating variable, significant ($p < 0.05$) inter-limb differences were found in the total group of players. When comparing between sexes, significant differences ($p < 0.05$) arose in the female group only. With regard to the WL vs. the SL, significant ($p < 0.05$) differences were noted in the whole group and when stratified into males and females. The mean ASI ranged from 9.31% (males) to 12.84% (females) and from 10.49% (males) to 14.26% (females), when comparing the DL vs. the NDL and the SL vs. the WL, respectively. Subjective expression of leg dominance cannot be used as a predictor of limb jump performance. Vertical jump asymmetry of 10-15% exists and this can be considered as a reference value for male and female basketball and volleyball players.

Key words: power, unilateral, imbalances, team sport games.

Introduction

Many sports are characterized by explosive, unilateral actions such as jumping and changes of direction. These conditions could lead team sport players to develop asymmetric neuromuscular adaptations of the lower extremities (Hewit et al., 2012; Menzel et al., 2013).

Substantial lower limb neuromuscular asymmetry with regard to strength and power has been described as an important risk factor for sport injuries and linked to decrements in sports

performance (Hewit et al., 2012; Impellizzeri et al., 2007; McElveen et al., 2010; Newton et al., 2006). The relationship between strength and power asymmetry and injury risk or poor performance could be related to the inability of a weaker lower limb to produce and / or absorb the same amount of force that a stronger limb can. Previous research suggests that lower limb imbalances exist in cutting and pivoting sports such as basketball (Theoharopoulos and Tsitskaris, 2000), soccer

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(Rahnama et al., 2005) and volleyball (Lawson et al., 2006; Markou and Vagenas, 2006). Moreover, these imbalances have also been identified in activities that have no rapid changes of direction such as running and cycling (Carpes et al., 2010). However, equivocal findings exist in the literature with regard to the presence (Plisky, 2006; Ross and Guskiewicz, 2004) or absence (Hewitt et al., 2012; Newton et al., 2006) of this asymmetry.

These performance differences between limbs can be linked to anatomical asymmetry (Blustein and D'Amico, 1985; Fousekis et al., 2010), previous injury history, such as anterior cruciate ligament (ACL) ruptures (Schiltz et al., 2009; Paterno et al., 2010), specific sport demands (Newton et al., 2006), training experience, a playing position and footedness (Fousekis et al., 2010).

The comparison of the unilateral neuromuscular capacity of the lower limbs is an important assessment and can provide insights related to performance, prevention, rehabilitation and return to play enhancement programs. There are several methods that can be used to assess these inter-limb differences. One of the most commonly used in the scientific literature is isokinetic assessment (Newton et al., 2006; Rahnama et al., 2005; Ross and Guskiewicz, 2004), but the necessary equipment is expensive and does not reflect the movement characteristics of the lower limb muscles during most sports activities. For these reasons, evaluating the unilateral jump capacity is one of the optimal, sports-specific methods to compare asymmetry between limbs (Ceroni et al., 2012; Meylan et al., 2009; Myer et al., 2011). This functional test is more specific, cheaper and involves the stretch-shortening cycle, directly associated with power (Hewitt et al., 2012), a success-determinant in many sports where unilateral actions predominate. There are a large variety of jumping tests to evaluate inter-limb unilateral power asymmetry (Meylan et al., 2009; Myer et al., 2011b; Noyes et al., 1991). Most human motion involves a complex interaction of vertical, horizontal and lateral force production, especially in sports where speed and agility are required, consequently, identifying one, definitive, limb asymmetry test is unclear. However, single-leg vertical jumping is suggested as one of the most sensitive tests to detect functional performance

asymmetry between legs (Ceroni et al., 2012; Maulder and Cronin, 2005; Stephens et al., 2005)

In order to find asymmetry, the lower limb asymmetry index (ASI) is commonly used in athletics to quantify neuromuscular deficits between legs (Ceroni et al., 2012; Overmoyer and Reiser, 2013). This index is used to identify athletes at potential risk for injury as the weaker limb is typically predisposed to injury (Hewitt et al., 2012).

When comparing inter-limb asymmetry, the most common way to categorize the limbs is to assign a dominant leg (DL) and a non-dominant leg (NDL) to each individual. It is extremely difficult, however, to predict which leg is dominant in sports such as soccer, volleyball or basketball due to the specificity of training in these events (Rahnama et al., 2005; Schiltz et al., 2009; Stephens et al., 2007). The literature demonstrates different methods to select the DL and the NDL. The dominant leg has been defined in a self-determined way as the kicking leg (Meylan et al., 2009; Theoharopoulos and Tsitskaris, 2000), the foot used for stair climbing (Ceroni et al., 2012) or the leg used to regain balance after an unexpected perturbation (Hewitt et al., 2012) and in a more functional way as the weaker (WL) and stronger (SL) leg (Ceroni et al., 2012) or the side with the highest single leg jump height (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 the DL to the NDL determined subjectively (e.g. the dominant leg as the kicking leg) may not be useful in detecting differences in neuromuscular capacities.

The inter-limb imbalance is frequently greater in female compared to male athletes in relation to strength, coordination and postural control (Myer et al., 2011). There are many studies reporting a higher ankle and knee joint injury incidence in women (Hewett et al., 2006). With respect to the latter, women show a greater number of specific injuries such as anterior knee pain (Fagan and Delahunt, 2008), the ACL rupture (Hewett et al., 2006; Paterno et al., 2010) and ankle sprains (Hosea et al., 2000). This greater number of injuries in female athletes has been related to neuromuscular factors, including the physical

capacity predominance of one leg over the other (Fort-Vanmeerhaeghe and Romero-Rodriguez, 2013; Hewett et al., 2010).

The determination of normative values for neuromuscular asymmetry has not been established in sports that have significant and rapid changes of direction such as basketball and volleyball. Therefore, the aims of the study were to: 1) evaluate the agreement between the perception of the dominant leg by the participants and the actual jump height reached by this limb in a group of male and female volleyball and basketball players, and 2) to evaluate the inter-limb jump height capacity and the ASI when comparing the dominant vs non-dominant leg (determined subjectively) and the stronger vs weaker leg (determined via a functional test) in the whole group and when differentiating by sex.

Material and Methods

A cross-sectional study was conducted to compare unilateral lower limb vertical jump height in a group of male and female volleyball and basketball players. These comparisons were made with respect to the following variables: DL/NDL and SL/WL.

Participants

Seventy-nine athletes were included in the study. Inclusion criteria consisted of basketball or volleyball players (18-35 years old) belonging to the Catalan or Spanish federation. All the selected teams trained a minimum of three times per week (approximately 6 to 10 hours), 8-9 months per year and played one match during the weekend throughout the duration of the season. Subjects with any injury (overuse or acute) or illness at the time of testing were excluded. All the participants provided written consent and the Ethics Committee of the International University of Catalonia approved the research protocol.

Procedures

Testing was performed within one session. Prior to testing, the age, stature, and mass of the subjects were recorded. The DL was determined from a questionnaire as the limb the subject would normally use to kick a soccer ball, the foot used to initiate stair climbing or the leg 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 stronger

leg was determined as the limb with the highest score in a single-leg counter-movement jump (Stephens et al., 2007).

Before testing, all the participants performed the following standard warm up: 4 min running followed by active stretching exercises (adductors, hamstrings, calf muscles, quadriceps and gluteus). Active stretching consisted of soft muscle eccentric actions (< 6 s). Following the warm-up, subjects were informed about testing procedures and were allowed to practice no more than 3 trials for each test. Vertical jump height testing consisted of three successful trials per limb of the single-leg countermovement jump test (SLVCJ).

Measures

Single-leg Vertical Countermovement Jump test (SLVCJ)

Flight time was calculated for each jump and subsequently vertical jump height (Bosco et al., 1983) with a contact mat system (Chronojump Boscossystem, Barcelona, Spain) (De Blas et al., 2012). This unilateral jump test was used to estimate inter-limb vertical jump height asymmetry. The test had previously been demonstrated to have good test-retest reliability (Hewitt et al., 2012; Maulder and Cronin, 2005; Meylan et al., 2009).

The protocol described by Meylan et al. (2009) was followed (Figure 1). The subject started with the foot of the selected leg on the contact mat with their hands on the hips. From this position, the subject was instructed to dip quickly (eccentric phase) reaching a self-selected depth to jump as high as possible in the ensuing concentric phase. The landing phase was performed on two feet. The knee of the uninvolved leg was held at approximately 90° of flexion. A trial was considered successful if the hands remained on the hips throughout and if balance was maintained for at least 3 s after landing. A recovery period of 30 s was given between each trial. Three trials were carried out with each leg, alternating right and left leg each time. The two best trials for each leg were averaged to obtain the mean score.

Statistical analyses

Descriptive statistics were derived (mean and standard deviation) for all the variables. A Shapiro-Wilk test was used to check the normality of the tested parameters. As the variables were

normally distributed; student t-tests were performed to compare the inter-limb differences in the whole group and when differentiating by sex: DL vs NDL and WL vs SL.

For the purpose of identifying neuromuscular asymmetry between limbs (DL vs NDL and SL vs WL), we also calculated the asymmetry index (ASI) using the following formula (Carpes et al., 2010; Impellizzeri et al., 2007):

$$\text{ASI} = (\text{DL} - \text{NDL} / \text{DL}) \times 100$$

$$\text{ASI} = (\text{SL} - \text{WL} / \text{SL}) \times 100$$

Statistical significance was set at $p \leq 0.05$. All statistical analyses were performed using SPSS software (version 20 for Windows; SPSS Inc., Chicago, IL, USA).

Results

Subjects' characteristics such as age, body mass, stature and BMI are presented in Table 1. Only in 32 (40%) of the subjects there was a concordance between the perception of their dominant leg and the limb reaching the highest jump height.

Using the DL as the discriminating variable, significant ($p < 0.05$) inter-limb differences were found in the total group of players. When comparing inter-limb differences between sexes, significant ($p < 0.05$) differences were identified in the female group only. With regard to the SL vs the WL, significant ($p < 0.05$) differences were noted for all subjects and when stratified into males and females (Table 2). Mean ASI values ranged from 9.31% (males) to 12.84% (females) and from 10.49% (males) to 14.26% (females), when comparing DL vs. NDL and SL vs. WL, respectively. Table 3 shows the percentage of subjects with the ASI > 15 %, which is considered as a potential sports injury risk factor.

Table 1

<i>Subjects' characteristics</i>			
	Females (n=38)	Males (n= 41)	Total (n=79)
Age (years)	23.2 ± 4.4	24.2 ± 4.7	23.7 ± 4.5
Stature (cm)	175 ± 7	189.1 ± 8.4	182.3 ± 6.2
Mass (kg)	69.8 ± 10	83.9 ± 9.3	77.1 ± 9.1
BMI (kg· m ⁻²)	23.2 ± 4.4	24.2 ± 4.7	23.7 ± 4.5
Right/left DL	37/1	33/8	70/9
SL was the DL	16	19	32

*BMI=body mass index, DL =dominant leg, SL =stronger leg;
DL was the SL if the leg described as the dominant was the limb
with the highest single-leg jump height*

Table 2

Total jump scores and comparison of the results by sex (Mean ± standard deviation)

	Comparison between sex		
	Total (n=79)	Females (n=38)	Males (n=41)
Dominant leg (cm)	14.23 ± 3.97	11.46 ± 2.62	16.79 ± 3.22
Non dominant leg (cm)	14.69 ± 3.67	12.33 ± 2.87	16.87 ± 2.94
<i>p</i>	0.029	0.002	0.786
ASI (%)	11.01 ± 7.48	12.84 ± 7.16	9.31 ± 7.44
Stronger leg (cm)	15.22 ± 3.81	12.68 ± 2.76	17.58 ± 3.07
Weaker leg (cm)	13.68 ± 3.69	11.10 ± 2.52	16.07 ± 2.91
<i>p</i>	0.000	0.000	0.000
ASI (%)	12.30 ± 9.48	14.26 ± 10.40	10.49 ± 7.96

ASI=asymmetry index

Table 3

The number and percentage of females and males with the ASI > 15%

	Total (n=79)	Females (n=38)	Males (n=41)
Dominant vs Non dominant leg	22 (27.84%)	12 (31.57%)	10 (24.39%)
Stronger vs Weaker leg	26 (32.9%)	13 (34.21%)	13 (31.7%)

ASI=asymmetry index

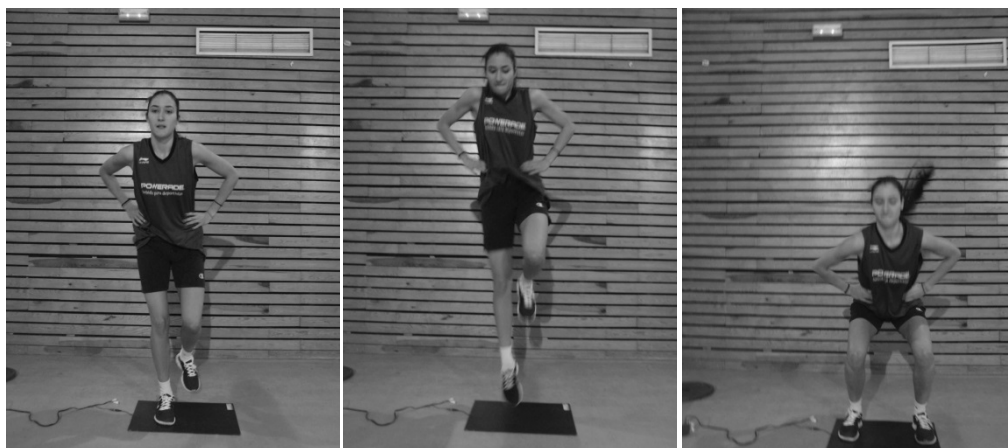


Figure 1

Single-leg vertical countermovement jump test with the right leg

Discussion

The main finding of this research was that the concordance between perception of the dominant leg and the limb reaching the highest jump height was low. In addition, when using SL vs. WL, there were significant inter-limb differences in vertical jump height and this was reflected by the ASI values of 10-14%. Another important finding of this study was that females tended to have a greater ASI than males.

Only 32 of the 79 participants of our study described their dominant side as the leg that subsequently generated better vertical jump height; this suggests that using this technique as the subjective tool for determination of the stronger leg is rather problematic. These results are in agreement with other authors (Ceroni et al., 2012; Stephens et al., 2007). According to Stephens et al. (2007) and Ceroni et al. (2012), using the DL as a predictor of jump height was accurate approximately in 50% of 25 volleyball players and 51% of 223 recreational sport teenagers, respectively. Although there are still some studies predicting the dominant leg subjectively (Hewit et al., 2012; Maulder and Cronin, 2005), this method can negatively affect the results and the interpretation of ASI determination. Consequently, subjective selection of leg dominance may not be a useful predictor of limb jump performance.

In the whole group, the SL generated greater jump height capacity than the weaker leg. Furthermore, when conducting an intra-group sex comparison for the SL vs the WL, there were significant differences in vertical jump height capacity in both male and female groups. When comparing the DL versus the NDL (chosen subjectively by the player), significant differences were found when the data were pooled (male and female). When the data were stratified by sex, significant differences were noted in the DL versus the NDL in females; however, no significant differences were found when comparing DL vs NDL in the male population. These significant differences between legs may be explained by sport-specific demands, such as unilateral jumping in volleyball and basketball players (Schiltz et al., 2009; Stephens et al., 2007). Moreover, team sport players tend to use one extremity more, allowing for better coordination and leading to a greater strength capacity of the

most used limb (Erculj et al., 2010; Stephens et al., 2007). These specific demands could lead to the development of asymmetric adaptations between legs. The results in the present investigation were similar to other studies (Ceroni et al., 2012; Meylan et al., 2010), who found significant differences between limbs in unilateral jump capacity. Evidence in the existing literature is, however, equivocal as some previous research (Hewit et al., 2012; Schiltz et al., 2009) demonstrated no significant difference in unilateral vertical jump capacity in healthy athletes. These differences may have arisen as a result of differences in training experience, the level of sport practice, specific sports demands, testing used to detect asymmetry and the injury history of the participants in the present study. Although the test carried out in the present study is primarily a functional test, evidence from the literature tends to show similar results both in non-functional (Rahnama et al., 2005; Ross and Guskiewicz, 2004) (strength isokinetic evaluation of quadriceps and hamstring muscles) and functional tests (Newton et al., 2006; Schiltz et al., 2009) (vertical jump).

The results from the present study and previous research suggest a 10-15% threshold of inter-limb asymmetry strength/power to be considered as normal physiological variability (Hewit et al., 2012; Munro and Herrington, 2011; Noyes et al., 1991; Paterno et al., 2010). However, there is a lack of consensus about the real relationship between inter-limb neuromuscular asymmetry and the potential risk of injury. Although there are some studies correlating the re-injury of the ACL (Paterno et al., 2010) and ankle ligament injuries (Ross and Guskiewicz, 2004) with inter-limb performance asymmetry. This has particular relevance to the present study, as 34.2% and 31.7% of female and male athletes, respectively, showed the ASI > 15%, which is considered as the threshold for potential risk of injury (McElveen et al., 2010; Noyes et al., 1991; Paterno et al., 2007). This inter-limb asymmetry has the capacity to increase injury risk and has an adverse effect on team sports performance (Haaland and Hoff, 2003), particularly in sports such as basketball, soccer and handball. These differences between limbs with regard to jump performance can result from multiple factors which could be related to previous anatomical

lower limb asymmetry (Fousekis et al., 2010), previous injury with incomplete recovery (Paterno et al., 2007; Schiltz et al., 2009), repetitive asymmetrical sport-specific demands (Newton et al., 2006), training experience and footedness (Fousekis et al., 2010).

With regard to sex differences, when using the SL vs the WL, women have greater limb vertical jump height asymmetry (14.3%) than men (10.5%). This value is in line with the findings of other authors that have demonstrated inter-limb neuromuscular deficits in strength, coordination, and postural control as being more common in female than male athletes, especially during adolescence (Ford et al., 2003; Hewett et al., 2010). The major neuromuscular asymmetry between legs in females could explain their higher injury incidence compared with males, such as the anterior cruciate ligament rupture (Myer et al., 2011).

Strength and conditioning coaches along with physiotherapists may use ASI values to detect healthy athletes who may be at risk of future injury and guide neuromuscular prevention programs. This injury prevention programs can provide corrective strategies to address asymmetry and potentially reduce the risk of injuries. However, there is a paucity of literature with respect to the optimum training programs to reduce excessive asymmetry and this question warrants further investigation. The preferable option to test the neuromuscular asymmetry would be functional tests for two main reasons: normally they do not need sophisticated equipment and the muscular and joint performance is more representative of the actual

movement in sport. Moreover, the test used in this study is an example of a movement that benefits from the stretch – shortening cycle. Many actions within sports such as basketball and volleyball require this type of neuromuscular capacity (Wilson et al., 2008). The next step to address the problem of inter-limb asymmetry is the design of sport programs to balance the performance capacity between each limb. This action could enhance injury prevention strategies and rehabilitation as well as return to sports practice after an injury, and could also increase the functional capacity of both limbs in order to perform better. There is scarce literature with respect to the optimum training programs to reduce these imbalances. The existing studies have considered both unilateral and bilateral training (Mccurdy and Langford, 2005; Myer et al., 2011), but no clear consensus can be drawn from these data.

Conclusions

Our study detected that only 40% of the players described the dominant leg as the leg with a better score in the SLVCJ. Consequently, based on the data from the present study, SL vs WL comparisons should be the optimal criteria used for inter-limb neuromuscular asymmetry identification. A 10-15% threshold of inter-limb vertical jump height asymmetry can be considered as the physiological norm in basketball and volleyball players. Our study also demonstrated that a high proportion (33%) of the players tested had the ASI higher than 15%. Based on the existing literature, all these players are under greater risk of injury.

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