Original Research

Lower Limb Symmetry

Comparison of Muscular Power Between Dominant and Nondominant Legs in Healthy Young Adults Associated With Single-Leg-Dominant Sports

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Background: Achieving a symmetrical power performance (difference <15%) between lower limbs is generally recommended during sports rehabilitation. However, athletes in single-leg-dominant sports, such as professional soccer players, could develop significant asymmetry between their dominant and nondominant legs, such that symmetry does not act as a viable comparison.

Purpose: To (1) compare maximal muscular power between the dominant and nondominant legs in healthy young adults, (2) evaluate the effect of a single-leg-dominant sport activity performed at the professional level, and (3) propose a parameter of normality for maximal power difference in the lower limbs of this young adult population.

Study Design: Controlled laboratory study.

Methods: A total of 78 healthy, male, young adults were divided into 2 groups according to sport activity level. Group 1 consisted of 51 nonathletes (mean ± SD age, 20.8 ± 1.5 years; weight, 71.9 ± 10.5 kg) who participated in less than 8 hours a week of recreational physical activity with nonspecific training; group 2 consisted of 27 single-leg-dominant professional soccer players (age, 18.4 ± 0.6 years; weight, 70.1 ± 7.5 kg) who specifically trained and competed at their particular activity 8 hours or more a week. For assessment of maximal leg power, both groups completed the single-leg squat jump test. Dominance was determined when participants completed 2 of 3 specific tests with the same extremity. Statistical analysis included the Student *t* test.

Results: No statistical difference was found for maximal power between dominant and nondominant legs for nonathletes ($t = -1.01$, $P = .316$) or single-leg-dominant professional soccer players ($t = -1.10$, $P = .281$). A majority (95%) of participants studied showed a power difference of less than 15% between their lower extremities.

Conclusion: Among young healthy adults, symmetrical power performance is expected between lower extremities independent of the existence of dominance and difference in sport activity level. A less than 15% difference in power seems to be a proper parameter to define symmetrical power performance assessed by vertical single-leg jump tests.

Keywords: muscle power; limb symmetry; single-leg-dominant athletes

Sports practice has expanded worldwide. As physical activity has increased, so has the number of injuries, especially among the young population.[13,42] For this reason, injury prevention and adequate rehabilitation have become topics of interest.[16] Insufficient evidence is available to determine the most effective rehabilitation method after injury and to establish the best time to return to sports to prevent reinjury.[29,39] Lack of consensus can be attributed to the variability between athletes, sports, and type of injuries. However, a general recommendation is that before returning to sports, athletes with leg injury should achieve symmetrical bilateral power between the injured

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leg and the uninjured leg, indicated by a difference less than 15%.[2,3,10,26,27,29,39]

Muscle power is defined as the amount of work a muscle can produce per unit of time. High muscle power is understood as the capacity to exert high levels of strength as quickly and explosively as possible.[20] Muscle power is considered a key factor for performance of jumps, kicks, shots on target, and acceleration,[30] which are relevant for sports such as soccer, football, rugby, volleyball, basketball, and swimming.[4,18,19,28,32]

Some have speculated that professional athletes who practice a specific sport that requires a constant preference of one leg over the other during training or competition (single-leg-dominant athletes), such as soccer,[5] could develop significant muscular power asymmetry between their dominant and nondominant legs.[5,31,35,41] However, no reported studies have evaluated power symmetry in professional young adult soccer players.

The aim of this study was to (1) compare maximal muscular power between dominant and nondominant legs in healthy young adults, (2) evaluate the effect of a single-leg-dominant sport, specifically soccer, performed at a professional level (understood as athletes who specifically train and compete at their particular activity for $\geq$8 hours per week) in this comparison, and (3) propose a parameter of normality for maximal power difference between lower limbs among this population.

The working hypotheses were as follows:

- No significant difference in maximal muscle power performance exists between the dominant and the nondominant leg in healthy young adults who practice recreational or nonspecific physical activity.
- A significant difference in maximal muscle power exists between the dominant and the nondominant leg in single-leg-dominant healthy, young adult, professional soccer players.

METHODS

The study sample was selected through a random-by-opportunity design (ie, convenience sampling) from a population of healthy young men between 18 and 30 years old. Students from the Universidad del Desarrollo of Santiago and division level soccer players from Club de Deportes Cobresal were invited to participate. Those with at least one of the following criteria were excluded from the study:

- Previous abnormality in the lower body that would potentially reduce lower limb performance (ie, club foot, chondromalacia patella, jumper's knee, etc)
- History of lower extremity surgery
- History of recent traumatic lower extremity lesion (<3 months)
- Pain or discomfort while performing the specific tests from the study

The sample size was estimated by use of a standard deviation (SD) of ±274 W for power, obtained through a pilot measurement in a reduced sample, which assumed an estimated error of 75 W and a 95% CI.

TABLE 1
Participant Demographics

Group	n	Age, y[a]	Weight, kg[a]
Nonathletes	51	20.78 ± 1.49	71.87 ± 10.53
Professional soccer players	27	18.41 ± 0.64	70.06 ± 7.52

[a]Data expressed as mean ± standard deviation.

The data were obtained during 2014 at the facilities of Universidad del Desarrollo and the sport fields of the Municipalidad de Puente Alto by 4 medical students, previously trained by the main author (A.V.) of this research.

Participants

A total of 78 healthy male young adults were enrolled and assigned to 1 of 2 study groups according to their sport activity level:

- Group 1: nonathletes, defined as individuals who participate for less than 8 hours per week in recreational physical activity with nonspecific training. This group included 51 university students.
- Group 2: single-leg-dominant professional soccer players, defined as athletes who specifically train and compete in soccer for 8 hours or more per week. This group contained 27 soccer players.

The demographic information of the participants in this study is detailed in Table 1.

Lower Limb Muscle Power Measurement

Maximal leg power was estimated through an equation provided by Sayers et al[36]:

$$Power = \{[Vertical\ Height\ Jump\ (\mathrm{cm}) \times 60.7] + [Participant\ Body\ Mass\ (\mathrm{kg}) \times 45.3]\} - 2055$$

Vertical height jump was assessed through the single-leg squat jump test[1,8,12,22,23,33,40] over an arithmetic platform (ie, a jumping platform with the capacity to measure flight height) as described by Dallas et al[12] modified from the Bosco et al[7] jump protocol. Each participant performed the jump test over a switch mat (Ergo Tester; Globus), which indirectly calculated the flight height of each single jump by using the flight time and the acceleration of gravity, with the following formula: $h = (tf^2 \times g \times 8)^{-1}$, where h is height, tf is flight time, and g is the acceleration of gravity.[12] The participant started the jump test from a single-leg semi-squatting position with 90° of knee flexion (measured with a standard goniometer) and both hands placed on each ipsilateral iliac crest. The participant maintained this position for 2 seconds before jumping vertically with maximal knee and ankle extension, trying to reach as high as possible (Figures 1 and 2). To familiarize participants with the jump technique, they performed 2 trials with each leg before the final measurement. This test

Figure 1. Modified single-leg squat jump test. A soccer player is set in position for a vertical jump on top of a switch mat (Ergo Tester; Globus), with the research team ready to record the data. The researcher on the right is certifying proper position of the athlete prior to the jump: single-leg semi-squatting position with 90° of knee flexion (measured with a standard goniometer) and both hands placed on each ipsilateral iliac crest.

Figure 2. Modified single-leg squat jump test. The soccer player performs a vertical jump with maximal knee and ankle extension, trying to reach as high as possible, with both hands kept over the iliac crests. The mat registers the jump height in order to calculate the athlete's muscle power.

was repeated 3 times with each extremity, and the best jump was considered for statistical analysis.

Each participant's mass was measured by use of the same Terraillon electronic weight scale.

Assessment of Lower Limb Dominance

To determine leg dominance, we required each participant to perform 3 specific tests[37] in which he had to instinctively choose one leg to achieve the task:

- Kicking a soccer ball (Brazuca; Adidas)
- Extinguishing a simulated fire
- Drawing figures in the ground

The dominant leg was defined as that chosen for performing at least 2 of these 3 specific tests. The participants were not previously aware of the purpose of these tests.

Statistical Analysis

A descriptive analysis of central tendency statistics was performed. To compare lower limb maximal power between dominant and nondominant legs, we used parametric Student t test for related (paired) samples. Prior to that, normal distribution for each variable was verified. Statistical significance was defined as $P < .05$.

The lower extremity index was calculated for each individual as described by Barber et al.[3] The normal value for the entire studied sample was established as that falling within the 95% of the studied participants (±2 SD).

The data were analyzed with SPSS software version 22.0 (SPSS Inc), and the sample size was estimated by operating EPIDAT 4.1 (PAHO software for epidemiological studies).

RESULTS

The results per group are summarized in Table 2. Among nonathletes, the mean height values and maximal power achieved for the dominant and nondominant leg showed no significant difference between extremities ($P = .32$). Among professional soccer players, the mean height values and maximal power achieved for the dominant and nondominant leg showed no significant difference between extremities ($P = .28$). Finally, 95% of the 78 participants presented less than 15% of power difference between their lower extremities, independent of their activity level (Figure 3).

DISCUSSION

After a sports-related injury, the patient's muscular power is an important parameter used in the rehabilitation process. An acceptable criterion for allowing athletes to return to full sport participation is attainment of less than 15% difference between the injured and uninjured limbs on kinetic and dynamic testing.[3,11,15,24,26,29,38] However, it has been speculated that professional athletes who practice a sport that requires a constant preference of one leg during training or competition (ie, single-leg-dominant athletes) could develop significant asymmetry between their dominant and nondominant legs.[5,35,41] To find this potential difference is of extreme importance because the muscular power in the contralateral (uninjured) lower limb is commonly used as a parameter to determine full return to sports after a lower extremity injury or surgery. If leg power was asymmetrical at baseline in single-leg-dominant athletes, then trying to achieve muscular symmetry between legs could mislead the rehabilitation protocol, predisposing the athlete to a reinjury.

TABLE 2
Maximal Height and Power of Lower Limbs for Nonathletes and Professional Soccer Players

	Maximal Height, cm			Maximal Power, W		
	Dominant Leg[a]	Nondominant Leg[a]	Mean Comparison	Dominant Leg[a]	Nondominant Leg[a]	Mean Comparison
Nonathletes	18.97 ± 4.85	19.38 ± 4.47	$t = -1.01$ $P = .316$	2352.96 ± 520.53	2377.84 ± 520.05	$t = -1.01$ $P = .316$
Professional soccer players	20.14 ± 2.13	20.65 ± 2.19	$t = -1.10$ $P = .281$	2341.28 ± 347.61	2371.86 ± 372.97	$t = -1.10$ $P = .281$

[a]Data expressed as mean ± standard deviation.

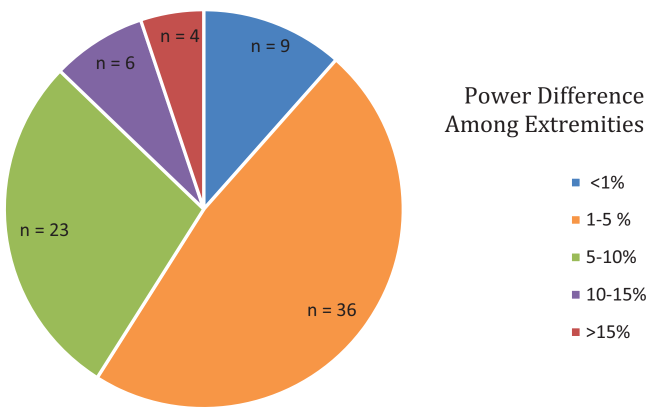

Figure 3. Total sample distribution for leg power differences between dominant and nondominant extremities, independent of the participant's activity level (N = 78).

Concordant with previous international publications,[6,21,25,35,41] the results of the present study demonstrate no statistical difference in maximal power between the dominant and nondominant legs in healthy young adults, whether they are nonathletes or professional, single-leg-dominant athletes. It is of particular interest that our study was performed on young adult men in Chile, where soccer is the most popular sport. The only study that has previously compared dynamic muscle strength between the preferred and nonpreferred legs in soccer players, published by Rahnama et al,[31] was performed in English players and used an isokinetic dynamometer. This study found that knee flexor muscles were significantly weaker in the preferred leg of soccer players, which the authors interpreted as an adapting phenomenon related to kicking. In our study, we found no differences in muscle power between lower extremities in the professional soccer group. This could be because we did not measure the extensor-to-flexor ratio or difference between the muscle groups but rather used a jumping activity, which involves multiple muscle groups.

Soccer was the chosen sport in this study. Soccer players have a constant preference of one leg over the other for kicking the ball and are considered single-leg-dominant athletes.[5] The idea that soccer players could develop asymmetry between their lower extremities has been previously reported.[5,35,41] In contrast, our study suggests that lower limb muscular power develops in a symmetrical way in single-leg-dominant athletes, regardless of the fact that one leg may be constantly chosen for leading an action (such as kicking a ball) and consequently could be more trained than the contralateral leg. A possible explanation for these results is that while the dominant leg exerts its specific action, the nondominant leg remains active, providing postural (stabilizing) support.[17] In other words, while the dominant leg is kicking the soccer ball, the nondominant leg is actively generating the knee and hip flexion and extension that are required to support the individual's weight.

Two studies have previously compared the performance of both lower extremities in single-leg-dominant athletes. Samadi et al[35] and Valdez[41] studied flexibility, balance, and power among 3 study groups: nonathletes, "one-legged athletes," and "two-legged athletes." Valdez defined "one-legged athletes" as athletes who train and compete in a skill that mainly focuses on one leg (eg, long jumpers, high jumpers, football kickers, etc). He defined "two-legged athletes" as those who train and compete in an activity that does not focus on one leg (eg swimmers, sprinters, long-distance runners). In support of our results, neither of these studies found a significant power difference between lower extremities, independent of leg dominance. Of note, the muscle power in both of these studies was evaluated by use of the single-leg hop for distance, which can be inaccurate because of differences in foot landing, foot length, and determining the starting and final distance. In our study we used a specific protocol for the single-leg squat jump test, which has been validated as a reliable tool for evaluating muscular leg power.[1,22,23,33,38]

We found that 95% of the study participants presented a lower extremity muscle power difference of less than 15%. Barber et al[3] introduced the limb symmetry index (LSI), which remains a commonly used tool for assessing whether muscle power through hop performance is normal.[1,38] In the study by Barber et al,[3] 90% of the participants (nonathletes) had an LSI of less than 15%, which was considered normal. Based on these results, we suggest that a difference of less than 15% between lower extremities indicates muscular power leg symmetry in our population.

A variety of features may limit the generalization of our results. All of the study participants were male adults between 18 and 26 years old, and for the single-leg-dominant athlete group, only soccer players were enrolled.

Leg power starts to decrease when people approach the age of 40 years.[14] We chose a younger study group because muscular power development reaches its peak between 18 and 30 years of age, so theoretically we had the best chance to find asymmetries in this age range.[34] Moreover, in 10-year-old soccer players, Capranica et al[9] did not find statistical difference for muscular power between the leg chosen for kicking and the contralateral leg, speculating that symmetry was found in this population due to a lack of muscular development.

It remains uncertain whether our results may be extrapolated to other cohorts such as females, different sports, or other single-leg-dominant activities. Regarding the female population, a study among ballet dancers showed no sex-related differences in muscular leg power, evaluated through a single-leg vertical jump.[43] Future studies should focus on searching for muscular power differences in other types of sports and in older athletes.

In conclusion, in this study group, symmetry (defined as <15% of muscle power difference) was found among lower extremities, independent of the side-to-side dominance and the level of intensity of physical activity. Therefore, during the rehabilitation process for lower limb injuries, the healthy leg may serve as a viable preinjury model for achieving performance on the injured leg in single-leg-dominant professional soccer players.

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