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Research Article

Effects of Lower-Limb Dominance on Isokinetic and Functional Profiles in Healthy Young Active Men – A Pilot Study

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Abstract

The effects of limb dominance on isokinetic and functional performance tests are still unclear and this correct understanding is needed to improve the ability of the clinician to evaluate lower limb injuries and their progression, especially in the sports arena. Thus, this pilot study proposed to investigate the influence of limb dominance on knee isokinetic evaluation and performance in functional tests and in the limb symmetry in healthy young active men. Fifteen male subjects (22.1 ± 3.0 years) from a college community took part in this study. Measurements of knee concentric and eccentric isokinetic evaluations (peak torque, acceleration time and deceleration time – to the knee flexion and extension) were carried out using a Biodex Multi-Joint System III isokinetic dynamometer at an angular velocity of 60º/s. Knee function was assessed by two functional tests: the hop test for distance and the one-legged vertical jump. No significant difference (α = 5%) in the isokinetic and functional profiles was found between the dominant and non-dominant limbs. Therefore it seems that the limb dominance does not decisively influence the limb symmetry in healthy young active men, or their exposure to one risk factors for musculoskeletal injuries, related to the bilateral asymmetry.

Keywords: *Limb Dominance; Isokinetics; Functional Tests; Lower Limbs; Performance*

Abbreviation

ACL: Anterior Cruciate Ligament

Introduction

Assessment of unilateral leg function is necessary after injury to effectively evaluate and monitor evolution of the rehabilitation process [1]. Routine progress assessments commonly use the uninjured leg performance as a reference for comparison, and typically these evaluations are limited because of the undetermined effects of leg dominance [2]. Failure to consider the existence of bilateral differences related to leg dominance could be problematic in testing situations where one leg serves as control for the other one.

An existing trouble with the study of dominance is the lack of consensus in the definition and determinants of limb dominance. By convention, it has been defined as one limb demonstrating increased dynamic control as a result of an "inter-limb imbalance" in muscular strength and recruitment patterns [3,4]. In the lower limb, it could refer to the leg that is used for mobility or fine motor activities, such as kicking a ball and picking a marble up with the toes, while the non-dominant limb contributes to posture and support [5,6].

Some authors have suggested that lower limb bilateral differences may represent a form of functional asymmetry, defined as a consistent task discrepancy between dominant and non-dominant lower limbs [7]. Therefore, these authors stated that side-to-side differences that may be common could affect the individual's ability during different unilateral and bilateral weight bearing tasks, which could increase the risk of injury [4,8].

However, the effects of limb dominance on isokinetic and functional performance tests are still unclear. The majority of previous studies comparing side-to-side leg strength found no difference between dominant and non-dominant legs [1,9-14]. Conversely, epidemiologic studies have shown not only that strength imbalances exist but that they may result in increased injury rates for athletes with side-to-side strength and functional differences greater than 10% [15].

One probable reason for this discrepancy between the results of experimental and epidemiological researches may lie in the fact that most of these studies evaluated the lower limb performance with respect to concentric muscle action alone, in which the muscle shortens [16] and exerts a force, which is transmitted via the tendon to the joint, enables movement to occur and causes a change in joint angle [17].

However, it is known that sports activities have a great demand of eccentric muscle action, in which muscle often increases in length when it is exerting force and be overcome by external resistance [16]. Eccentric contractions were characterized by high intensity deceleration and acceleration forces which allow the dissipation of mechanical energy during body deceleration and the conversion of kinetic energy into elastic energy of tendons [17]. Thus eccentric actions are directly related to the control of excessive movements, which are one of the main factors associated with most sports injuries [18]. Therefore some studies have suggested that the reaction time is an essential element in joint protection against injuries, because joint loading, especially in sports activities, requires fast and coordinated muscle action [19,20].

In this way, recent reports have indicated that the ability to produce torque quickly [21] and the muscle acceleration [19] and deceleration times [22] represent a better indicator of functional performance than peak torque alone. Acceleration time, defined as "the time required to accelerate the testing limb to a preset dynamometer speed", may provide valuable information with respect to neuromuscular ability to produce maximal muscle action [20,24], whilst deceleration time, defined as "the total time to go from isokinetic speed to zero", indicates the neuromuscular ability to eccentrically control movement towards the end range of the movement, and plays an important role especially during fast and self-terminated movements [22,23]. However, although speed, deceleration and acceleration are important parameters of motor function, unfortunately they have been less investigated than strength and endurance [19,20].

In addition, the comparison of bilateral deficits in functional performance tests may be a crucial role given their close relationship with sports movements and gestures. Single-leg hop tests and vertical jump tests are commonly used to study knee function in patients with an anterior cruciate ligament (ACL) injury, and are designed to reflect the demands of a high level of physical activity [10,25-27]. Research on this topic would give support to the assessment prior to participation in high intensity activity, in order to detect asymmetries and provide training to improve deficiencies and reduce the risk of injury [1,28]. A correct understanding of the effects of leg dominance on lower limb performance will improve the ability of the clinician to evaluate lower limb injuries and their progression, especially in the sports arena [25]. Therefore, this pilot study proposed to investigate the influence of limb dominance and the limb symmetry on the concentric and eccentric knee isokinetic evaluations and performance in functional tests, in subjects with no prior history of knee injury.

Materials and Methods

Subjects

Fifteen male subjects (22.1 ± 3.0 years old) from a college community, served as the participants in this pilot study. The mean height was 175.0 ± 8.5 cm (range 165 - 187 cm) and the mean weight was 73.0 ± 8.1 kg (range 59 - 84 kg). Women were not included in order to maintain a homogeneous sample. To be included, the subjects had to meet the following criteria: a) no prior history of unresolved pain, injury or surgery to either hip, knee or ankle joints; b) no upper extremity injury (that would hind their ability to reach during jumping); c) only occasional exercise and no regular physical activity (less than three times a week); d) no history of a neurological condition affecting lower extremity function; e) no apparent loss of balance

Having received an explanation of the risks, benefits and procedures of the study, the subjects signed a consent form prior to undergoing testing, and the study was approved by the Ethics Committee of the University.

Procedures

All subjects were submitted to an initial evaluation where they were assessed with respect to the selected physical characteristics and underwent patient medical screening. Loss of balance was assessed via the single leg stance test, where the subjects had to hold the position for a minimum of 30 seconds without loss of balance to be included. Limb dominance was determined for each subject by identifying the leg with which he would preferably kick a ball [12,29-32]. The right knee represented the dominant knee in 11 subjects (73.3%).

The order of testing was performed in a typical manner for this clinical setting: a brief warm-up session, followed by the isokinetic testing and finally the functional assessment. A practicing sports and orthopedic physical therapist with 8 years of clinical experience administered all the tests and collected the data. The subjects were instructed to perform a standardized warm-up prior to the isokinetic test. The general warm-up consisted of 5 minutes of stationary bicycle at 25 km/h, and static stretching of the quadriceps, hamstrings and gastrocnemius muscle groups for both lower extremities for 1 minute (for each group) [12,21].

The measurements of concentric and eccentric isokinetic peak torques, and the acceleration and deceleration times of the quadriceps and hamstring muscles were taken using a Biodex Multi-Joint System III isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY, USA) at an angular velocity of 60º/s [21,30,33,34]. The dynamometer was calibrated according to the manufacturer's protocol prior to data collection. The subjects were tested in a seated position with 100º of hip flexion and 90º of knee flexion (0º being full knee extension) on the dynamometer chair, and were secured with straps across the chest, pelvis and thigh [34]. The resistance pad was placed as distally as possible on the tibia, while still allowing full dorsiflexion at the ankle. The rotation axis of the dynamometer was aligned as accurately as possible with the femoral lateral epicondyle (flexion-extension axis of the knee). The range of motion was set at 20º - 90º of knee flexion to minimize the discomfort and interference caused by any eventual muscular tightness. The subjects were allowed to grasp the system handgrips to stabilize the body during the test. All limbs were gravity compensated according to the specifications outlined by the manufacture's service manual [25].

Before starting the actual test, a standard adaptation session was applied, including a detailed explanation of the differences between concentric and eccentric contractions, giving the subjects the opportunity to experience how these muscle actions were going to be tested. The subjects were allowed a trial test as a specific warm-up and to familiarize themselves with the equipment and the test procedure (concentric-concentric). Following a two-minute rest period, eight maximal reciprocal concentric isokinetic knee extensions and flexions were performed. After a three-minute rest period, the subjects proceeded with a new trial test to familiarize themselves with the other test procedure (eccentric-eccentric). Following a two-minute rest period, eight maximal reciprocal eccentric isokinetic knee extensions and flexions were performed. Standardized verbal commands and encouragement were given and the participants were provided visual feedback of the performance [35]. However, knowledge of the results of the test was withheld until all the tests were completed [25]. The same protocol was repeated with the opposite leg and the order of limb testing was randomized with respect to the dominant and non-dominant limbs [32].

Knee function was assessed by the hop test for distance and the one-legged vertical jump. The subjects received a brief explanation about the functional tests and were instructed to perform a new standardized warm-up prior to the functional test session. The general warm-up required participants to jog for 5 minutes, and carry out static stretching of the quadriceps, hamstring and gastrocnemius muscle groups for both lower extremities for 1 minute (for each group). Trials for each functional test (task-specific warm-up) were allowed, for familiarity with the actions required [31] and to ensure competence and understanding of the instructions for the testing procedures.

For the hop test, the subjects were asked to stand on one limb with the heel positioned on the zero mark of a tape measure. The subjects were instructed to maintain both hands behind their back to eliminate their use in generating momentum [11,34,36] and then asked to execute some trials (to increase the safety) by hopping horizontally and landing on the supporting limb. Finally, three maximal efforts, with the subject hopping as far as possible, were executed. This was followed by a 30-second rest time between the trials [31]. The criteria for a successful jump required the subject to maintain the landing for a minimum of 2 seconds while the measurement (heel to heel) was recorded with a standard measuring tape. A failed jump consisted of loss of balance, touching the floor with the contralateral limb or both upper extremities, or an additional short hop on landing [35,37], and resulted in a re-hop. The same protocol was then carried out with the opposite leg.

For the vertical jump, the subjects were positioned standing beside a wall with a paper panel. The subjects marked the distal portion of the third finger with ink, and standing reach baseline measurements were then taken for the subjects standing barefoot and reaching as high as possible first with the right and then with the left upper extremity. The subjects were then encouraged to jump as high as possible from a single-leg standing position (the opposite lower-extremity in non-support) and touch the paper panel with the ipsilateral upper-extremity to record the jump. The contra-lateral upper-extremity was maintained behind the back to eliminate its use in generating momentum [3,34] and avoid maximizing the height of the jump. Finally, three maximal efforts with the subject hopping as high as possible were executed. This was followed by a 30-second rest time between trials. The criterion for a successful jump was the same as that used in the one-legged hop test. The standing baseline reach was subtracted from each vertical jump score to obtain the height jumped [27]. The order of limb testing was randomized [32] and each leg was tested three valid times.

Data Analyses

The statistical analysis was carried out using the STATISTICA 5.0 for Windows software (StatSoft, Inc, Tulsa, USA). The means and standard deviations were calculated for all the variables using standard statistical procedures. Shapiro-Wilks test was used to test the normality of distribution. Accordingly the paired T-tests or Wilcoxon tests were used to compare the differences between the scores of the dominant and non-dominant limbs for each dependent variable (quadriceps peak torque, quadriceps acceleration time, quadriceps deceleration time, hamstring peak torque, hamstring acceleration time and hamstring deceleration time) for each contraction mode (concentric and eccentric) and for each dependent variable (hop test for distance and one-legged vertical jump) of the functional tests. The level of significance α was set at 5% for all statistical analyses.

Results and Discussion

Table 1 shows the means and standard deviations obtained for all the isokinetic and functional variables. According to these results, no significant difference was found between the dominant and non-dominant limbs with respect to isokinetic concentric (p-value ranging from 0.08-0.98) and eccentric (p-value ranging from 0.14 - 0.79) performance. Also, no bilateral difference was found in the functional profiles of the hop test for distance ($p = 0.68$) or in the one-legged vertical jump ($p = 0.44$).

Variable	Dominant limb	Non-dominant limb	p-value
QC peak torque (Nm)	179.1 ± 20.5	186.9 ± 26.9	0.08
QC acceleration (ms)	32.7 ± 13.3	33.3 ± 13.4	0.82
QC deceleration (ms)	170.0 ± 100.9	170.7 ± 81.5	0.98
HC peak torque (Nm)	93.2 ± 18.7	96.7 ± 13.8	0.41
HC acceleration (ms)	46.7 ± 15.4	50.0 ± 26.7	0.58
HC deceleration (ms)	252.7 ± 76.3	254.7 ± 73.2	0.94
QE peak torque (Nm)	238.0 ± 52.8	244.7 ± 61.9	0.47
QE acceleration (ms)	834.0 ± 713.4	933.3 ± 430.7	0.14
QE deceleration (ms)	386.7 ± 165.1	446.7 ± 154.0	0.30
HE peak torque (Nm)	130.0 ± 22.4	131.8 ± 24.1	0.69
HE acceleration (ms)	116.7 ± 51.2	134.0 ± 52.3	0.30
HE deceleration (ms)	96.0 ± 5.1	96.7 ± 4.9	0.79
Hop test for distance (cm)	146.3 ± 14.9	147.4 ± 15.6	0.68
One-legged vertical jump (cm)	21.5 ± 4.6	20.9 ± 3.8	0.44

Table 1: *Quadriceps and hamstring isokinetic profiles and functional performance for dominant and non-dominant limbs (n = 15).*

QC: Quadriceps Concentric; HC: Hamstrings Concentric; QE: Quadriceps Eccentric; HE: Hamstrings Eccentric
Values are means ± SD.

This pilot-study resulted from the need to describe and compare the isokinetic and functional aspects of dominant and non-dominant limbs during both concentric and eccentric activities in male subjects. In this context, no significant differences were found in isokinetic strength between the dominant and non-dominant limbs. This finding agrees with some studies [1,9-14,38] but disagrees with others [28,30,33].

Greenberger and Paterno [11] evaluated isokinetic concentric knee extensor strength in 20 male and female students using the Kinetic Communicator (KinCom) at 240º/s, and reported no significant differences between the dominant and non-dominant legs, while Hageman., *et al.* [12] showed no significant differences in torque values and torque/body weight ratios between the dominant and non-dominant limbs during eccentric and concentric activity. Despite the methodological differences, McCurdy and Langford [1] found no differences in unilateral squat strength between the dominant and non-dominant legs in men and women, whilst other studies [9,38] showed no significant differences amongst soccer players between the dominant and non-dominant isokinetic leg strength during knee flexion/extension. These studies indicated that, on the whole, muscle performance was similar between the dominant and non-dominant limbs for both activities performed in an open kinetic chain and in a closed kinetic chain.

However, varying results were found in earlier studies comparing the concentric activity of the dominant and non-dominant knees. Ross., *et al*. [28] found greater isokinetic concentric strength in the dominant knee than in the non-dominant one in young adult men at 60º/s, whilst Kellis., *et al.* [30] found significantly greater strength in the preferred leg than in the non-preferred leg in 158 soccer players, and Kong and Burns [33] showed that the isometric and isokinetic hamstring peak torque at 300º/s was higher in the dominant leg. All these studies indicated that the dominant limb had better performance than the non-dominant limb, in contrast to the present findings.

In the present study, the quadriceps and hamstring strengths were tested concentrically and eccentrically by eight maximal contractions at 60º/s, using the Biodex dynamometer, and no other study used a protocol identical to this one. Although the methods used in the different studies varied with respect to the equipment utylized (Biodex, Cybex or KinCom), muscles tested (flexors, extensors or both), muscle action (concentric, eccentric or both), test speed (ranged from 30 to 300º/s), type of familiarization (submaximal or maximal), test repetitions (3 to 8), order of testing (speed and muscle action), rest periods (30 seconds to 5 minutes) and variable measured (peak torque, average torque, total work), comparisons between the legs were still valid so long as the methods used on the one side were identical to those used on the other [8,25].

In addition, a novel result from this study was that other variables such as the acceleration and deceleration times of the quadriceps and hamstrings showed no significant bilateral differences in healthy men, indicating that not only the strength variables, but also those related to temporal aspects of muscle contraction remain similar between the dominant and non-dominant limbs. One explanation for the present results could be related to the sample profile. The individuals who took part in this study were control active and did not practice regular physical activity. In this case, there could be a less favorable environment to develop asymmetric leg strength and reaction muscle time, since the lower extremity work required in most daily life activities (e.g. walking, running, stair climbing) is usually bilateral.

It is important to mention that it might be interesting to associate the peak torque measurements with other isokinetic parameters, because it is not clear if and how muscle weakness could affect motor unit recruitment, especially when the muscle is still able to exert the force needed [24]. However, it seems that a functional assessment is needed to provide more details about muscle performance, since it simulates situations that are common in sports activities. In this way, the results of this pilot-study also revealed that no significant differences existed between the dominant and non-dominant limbs in the functional tests performed. This finding agrees with other studies [10,27,39]. Petschnig., et al. [10] found no significant differences between the dominant and non-dominant legs in the one-leg vertical jump, single-leg hop test and triple hop-test, while Barber., et al. [27] showed no statistical difference between the dominant and non-dominant limbs in the five functional tests used. In the same way, Caffrey., et al. [39] found no functional differences between the sides in healthy subjects, thus suggesting that limb dominance does not play a role in the performance of functional tests.

Thus the results of the present study suggest the existence of a functional symmetry between the lower limbs, and dominance appears to have no effect on lower limb symmetry. The results of this investigation are also useful in providing additional information about the activity of the hamstrings and quadriceps in healthy young males during both eccentric and concentric activity, as well as in the functional performance. These findings are timely because of the widespread use of isokinetics and functional tests in evaluation and rehabilitation.

Clinically, another aspect that should be considered is the possibility of eliminating the need for pretest scores as a baseline or the use of a control group [19], because the uninjured limb can be used for comparison. Also, similar criteria can be used for the dominant and non-dominant legs to determine the unilateral capacity, using the uninjured leg as the standard in subjects who do not repeatedly perform asymmetric activity. After injury, the subject may have to change his preferred leg with or without an associated change in the functionally dominant leg. This is another relationship where information concerning physiological adaptations of the body associated with injury may be beneficial to the clinician [2]. When a large asymmetry is present, its may be a function of an acute or chronic injury and not due to functional leg dominance.

This study had several limitations, some alluded to heretofore. First, the sample was one of convenience. As a consequence, it may have been healthier than the population as a whole, and less conditioned than an athletic sample. Thus, these results may not directly apply to athletes or rehabilitation patients. Second, because small subject samples were used, true random sampling of the groups may not have been represented. Thus caution is advised when applying the results of this study to other populations. Third, just one isokinetic velocity (60º/s) was used, and it would be interesting to verify these conditions throughout the whole spectrum of velocity.

The last and maybe the most important aspect to consider is the method used to classify lower limb dominance. The subjects were asked to indicate which leg they would preferably use to kick a ball, and the kicking limb was considered to be the dominant limb. While it seems appropriate to ask healthy adults about "which leg would you use to shoot the ball" to determine leg dominance in bilateral mobilizing tasks [40], this may be does not represent that in non-kicking tasks, such as jumping and landing, the dominant was the more functional limb. While the presence of upper-limb functional asymmetries is obvious (i.e. handedness), many tests exist to verify lower limb dominance. These tasks include kicking a ball, stepping up onto a chair, picking up pebbles with the toes, and tapping out the rhythm to a melody. In these activities, the non-dominant limb is generally used to support body weight, while the dominant limb provides the propulsion or performs the dexterous tasks [7].

Since there is no clear criterion against which to validate the present measurements, the selection of assessment procedures was mainly guided by personal predilection. Consequently, one study varies from the next in the precise way in which footedness is assessed, making it difficult to determine whether the differences between the studies are meaningful or just a consequence of procedural variation. Thus findings that contrasted with those of other studies may have been the result of different study designs, instrumentation, sample composition and size, methods used for data collection and analysis or recruitment profiles of the preferred versus the non-preferred foot.

In order to plan a complete rehabilitation program and to correct possible imbalances which may predispose the subjects to injuries, it is necessary to measure both the concentric and eccentric muscle action variables [29], both in open and closed kinetic chains, associated with aspects of functional performance. Thus, future research should focus on larger populations using velocity spectrum testing before definitive conclusions may be made about the relationship of limb dominance and the isokinetic and functional profiles.

Conclusion

The dominant and non-dominant leg isokinetic and functional performances are similar in healthy young active men. Thus, limb dominance does not appear to decisively influence limb symmetry or the exposure to risk factors for musculoskeletal injuries (related to the bilateral asymmetry) in this population.

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Conflict of Interest

Authors declare that there is no any financial and/or conflict of interest.

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