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**Original Article**

# Isokinetic performance of knee extensors and flexors in male weightlifters

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**Abstract:**
Weightlifting is a sport in which the athlete attempts to lift a barbell loaded with weight plates and the biomechanical demands of the lower limbs joints change. Thus, weightlifting plays a direct role to the knees involving their main extensor muscle groups and knee flexors. The present study used isokinetic evaluation to analyze muscle performance of the knee extensor and flexor muscles in male weightlifting athletes. The results demonstrated no statistically significant differences between the limbs, whether for mean peak torque values or for the flexor/extensor ratio. However, the results demonstrated muscle imbalances between the flexors and extensors, with the mean flexors PT values lower than expected when compared to the extensors. This result highlights the importance of training to increase the performance of the flexor muscles to reach an ideal level in relation to the extensor, thus improving athletic performance and preventing musculoskeletal injuries.
**Key words:** weightlifting; knee; muscle; torque.

## Introduction

Weightlifting is a sport in which the athlete attempts to lift a barbell loaded with weight plates (Chiu & Schilling, 2005; Larrat et al., 2007; Janz et al., 2008). This field of sport is widespread with its first international federation founded in 1905, recognized by the International Olympic Committee (IOC) in 1914 and became a permanent field of sport in the Olympic Games in Antwerp in 1920 (Stone et al., 2006). The main characteristic of the weightlifting is lifting the largest load possible in the shortest amount of time (Chiu & Schilling, 2005; Da Fonseca et al., 2007). Thus, athletes exhibit high rates of muscle activation, high peak power (Storey & Smith, 2012) and many musculoskeletal adaptations resulted by specific training (Chiu & Schilling, 2005). The startup movements (snatch) and the pitch (clean & jerk) are the movements that comprise the weightlifting practice (Janz et al., 2008; Storey & Smith, 2012). These movements are performed in phases that range from 3 to 5 seconds of duration and include an initial pull with knees straight leading the barbell to the level of the knees (start), followed by a transition period in which the torso moves to an upright position, and so the second pull occurs with an acceleration to raise the bar above the shoulder level and then extending the hips and knees bilaterally (clean & jerk) (Faigenbaum & McFarland, 2008; Storey & Smith, 2012). Weight lifting demands high technical levels since it requires controlled, quick and explosive combined movements (Faigenbaum & McFarland, 2008).

When lifting weights, the biomechanical demands of the lower limbs joints change (Kipp et al., 2011) – the extension of the hips and knees increases acceleration and thus contributes to a correct and efficient execution of the movements (Gourgoulis et al., 2009). Regarding the knees, weightlifting plays a direct role to the knees involving their main extensor muscle groups and knee flexors, quadriceps and hamstrings respectively (Mafra et al., 2011; Storey & Smith, 2012). Therefore, the study of the knee joint muscle performance is extremely important for improving muscular performance and preventing the incidence of injuries by weightlifting athletes. Thus, the isokinetic evaluation, for being an evaluation method of great validity and reliability, may be used in order to verify muscular performance of these athletes (Bruyère et al., 2016). This study aimed to analyze, collecting information from a database, the muscular performance and the differences of the extensor and flexor muscles between dominant limb (DL) and non-dominant limb (NDL) in amateur male weightlifters.

## Methods

*Participants*

This is a quantitative, cross-sectional and retrospective study conducted at the Instituto de Medicina do Esporte e Ciências Aplicadas ao Movimento Humano da Universidade de Caxias do Sul (IME-UCS) in the city of Caxias do Sul, Rio Grande do Sul, Brazil. It has been approved (protocol number 967.527) by the Ethical Research Committee of the Faculdade Cenecista Bento Gonçalves (Bento Gonçalves, Rio Grande do Sul,


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Brazil), and conducted according to the 2012 Law N°466 of the National Health Council and Helsinki Declaration, that approves the guidelines and rules for research involving human beings. The information provided by the IME-UCS' database concerning the concentric isokinetic evaluation of the knee extensor and flexor muscles from 10 male amateur weightlifting athletes were part of this study sample. The number of participants was conveniently established and, therefore, determined intentionally and not by probability according to the number of available evaluations in the IME-UCS's database. The evaluations in which the respective IME-UCS consent term had not been authorized by the athletes were excluded from this study. The mean age of the athletes was 28.10 (±0.49) years, mean height was 1.74 (±0.03) meters and mean weight was 100.94 (±10.26) kilograms. Among the tested athletes, 9 reported a dominance of the right limb and just 1 reported dominance of the left limb.

*Procedure*

These evaluations were made with the IME-UCS' isokinetic dynamometer (Biodex System 4®, Biodex Medical Systems, Shieley, New York, USA). The athletes first underwent warmup exercises on a stationary bicycle for 8 minutes at moderate velocity. The athletes were then leaded through the isokinetic dynamometer. The athletes sat on the dynamometer chair with their torsos leaning at 85°, stabilized with belts around the torso, pelvis, and thigh (1/3 distal) to avoid compensatory movements, with the motor axis aligned to the knee joint axis. Tests were first performed on the dominant limb (DL) and next on the nondominant limb (NDL). The athletes performed three sub-maximal repetitions and a previous maximal for each test on all four velocities to familiarize themselves with the procedures and warmup. Protocol during the test demanded 5, 10, and 20 maximal repetitions of knee extension and flexion in concentric-concentric mode on an angular velocity of 60°/s, 120°/s, and 240°/s. A 1-minute rest period was set between evaluations of different velocities, and a 3-minute rest period between DL and NDL evaluations. Athletes were tested by the same examiner with the use of verbal incentives to stimulate them throughout the process and to encourage the maximum use of their strength potential.

*Statistical analysis*

Isokinetic variables – peak torque (PT, N/m) and the flexor/extensor ratio (%) – were used for the analysis. The means values for PT and the flexor/extensor ratio for the knee joint musculature were evaluated statistically on the SPSS 17.0 software (Statistical Package to Social Science for Windows). To verify the normality of the data distribution, the Shapiro-Wilk test was used, and the mean values for the DL and NDL evaluations were submitted to the student's T test with a resultant level of significance of 0.05.

**Results**

We accessed isokinetic evaluations from 10 male amateur weightlifting athletes. The concentric isokinetic data results, the PT of the DL and NDL are presented in Table 1. At an angular velocity of 60°/s, 180°/s, and 240°/s, the average values for PT knee extensor and flexor muscles showed no significant differences between the limbs.

Table 1. Mean and standard deviation values for peak torque of the extensors and flexors of the dominant limb and the non-dominant limb's knee.

| Velocidades Angulares | PT Extensors (N/m) | | | PT Flexors (N/m) | | |
|---|---|---|---|---|---|---|
| | MD | MND | "*p*" | MD | MND | "*p*" |
| 60°/s | 324.93 ± (34.84) | 319.82 ± (48.61) | 0.72 | 160.58 ± (14.26) | 163.58 ± (23.54) | 0.60 |
| 180°/s | 203.96 ± (20.82) | 199.10 ± (19.41) | 0.38 | 114.09 ± (15.82) | 116.65 ± (16.95) | 0.58 |
| 240°/s | 154.77 ± (10.99) | 153.34 ± (19.50) | 0.77 | 90.53 ± (12.68) | 95.11 ± (20.92) | 0.42 |

DL = dominant limb, NDL = non-dominant limb, PT = peak torque.

Table 1. Mean and standard deviation values for the flexor/extensor ratio of the dominant limb and the non-dominant limb's knee.

| Angular Velocities | Flexor/Extensor ratio (%) | | |
|---|---|---|---|
| | MD | MND | "*p*" |
| 60°/s | 49.76 ± (5.34) | 52.33 ± (11.89) | 0.50 |
| 180°/s | 56.42 ± (9.84) | 59.03 ± (9.70) | 0.37 |
| 240°/s | 58.65 ± (8.03) | 62.75 ± (15.77) | 0.39 |

DL = dominant limb. NDL = non-dominant limb.

**Discussion**

This study aimed to analyze the average scores of peak torque (PT) and the ratio flexors/extensors (ratio Fle/Ext) of the knee joint of weightlifters through an isokinetic evaluation performed at angular speeds of 60°/s, 180°/s and 240°/s. Analyzing the knee muscular functionality has become a common practice since it is of great interest to evaluate and identify muscle imbalance (Almosnino et al., 2012). The isokinetic dynamometry is considered to be the gold standard in the analysis of muscular performance allowing a constant angular speed, and, consequently, the muscular evaluation throughout all the range of motion (Tsiros et al., 2011; Caruso et al., 2012).

Through the results of the isokinetic evaluation, it can be noted that the comparison between the DL and NDL, the average PT scores of extensors and flexors and ratio knee Fle/Ext showed no statistically significant differences at any angular speed analyzed. Unlikely other sports such as soccer (Fousekis et al., 2010) and futsal (Ferreira et al., 2010) which have asymmetrical muscle requirements from the extensor and flexor knee muscles, the weightlifting requires bilateral symmetrical muscle functioning from these muscle groups (Preto et al., 2014; Reiser et al., 2014). In the analysis of the average PT scores of the extensor and flexor muscles at angular speed 60º/s, both limbs showed average scores higher than the average scores found in other sports such as soccer (Zakas, 2006; Fousekis et al., 2010; Eniseler et al., 2012; Daneshjoo et al., 2013), futsal (Ferreira et al., 2010), rugby (Brown et al., 2014), basketball (Schiltz et al., 2009; Carvalho et al., 2011), handball (González-Ravé et al., 2014), and volleyball (Markou & Vagenas, 2006; Shu & Zhou, 2011). However, two studies which analyzed professional soccer players showed higher average scores of flexors than the scores of the athletes of this study (Zabka et al., 2011; Daneshjoo et al., 2013). Compared to other sports at angular speed of 180°/s, a few studies have shown average scores of the extensors lower than those of this study, similarly to the studies which analyzed futsal players (Ferreira et al., 2010), and soccer (Zakas, 2006; Fousekis et al., 2010; Silva et al., 2015), whilst other studies analyzing soccer players showed higher average scores (Da Fonseca et al., 2007; Daneshjoo et al., 2013). In the analysis of the knee flexors, studies with futsal players (Ferreira et al., 2010) and soccer (Zakas et al., 2006; Fousekis et al., 2010; Daneshjoo et al., 2013; Silva et al., 2015) also showed lower average scores whilst other studies showed average scores higher than the athletes of this study (soccer (Da Fonseca et al., 2007), rugby (Larrat et al., 2007) and handball (González-Ravé et al., 2014). At angular speed of 240º/s, all fields of sport analyzed (soccer (Zakas, 2006), rugby (González-Ravé et al., 2014), basketball (Schiltz et al., 2009) and volleyball (Shu & Zhou, 2011)), resulted in average scores higher than in this study, for both knee extensors and flexors.

Several complex physiological adaptations occur to weightlifters, placing them in the position of a select group of athletes due to their strength and muscular performance (Storey & Smith, 2012; Storey et al., 2016). The startup and pitch movements are greatly responsible for the lower limbs muscle development (Channell & Barfield, 2008; Arabatzi & Kellis, 2012), mainly of the quadriceps, hamstrings and gluteus maximus (DeWeese et al., 2012). Other studies had already shown that the muscular demand required during the weightlifting practice results in a great increase of strength of lower limbs, and, consequently, of the PT when compared to other training methods from different fields of sport (Tricoli et al., 2005; Khamoui et al., 2011; Otto et al., 2012). Nevertheless, when compared to other fields of sport, the best results of weightlifters were at slow speed (60º/s). According to Hedrick & Wada (2008), such results are due to the athletes' training program, which is made up mainly of exercises performed at slow speed and thus require greater strength. Although the beginning of the lifting is an explosive movement, the subsequent movements are performed at slower speed, which, consequently, requires greater PT at slow speeds (Fry et al., 2003; Chiu & Schilling, 2005), whilst in the majority of sports the muscle demands occur at faster speeds. According to Mazuquin et al. (2015), at slower speeds the muscle activation is greater: both for fast and slow twitch muscle fibers, different from faster speeds that have a shorter period for recruiting slow twitch muscle fibers.

Concerning the ratio Fle/Ext representing the strength proportionality of the hamstrings (flexors) in relation to the quadriceps (extensors), the results have shown that the weightlifters have average scores of DL and NDL below the one suggested by literature at all angular speeds analyzed. These results indicate muscle imbalances between extensor and flexor muscles of the knee for both limbs due to deficits of the flexors when compared to the knee extensors. The ratio Fle/Ext scores are often determined by the concentric PT of the extensor and flexor muscles (Kong & Burns, 2010). 60% is used as benchmark at angular speed of 60º/s (Grygorowicz et al., 2010) and can reach up to roughly 80% with the increase of speed (Andrade et al., 2012), scores not reachable by the analyzed athletes. The literature review by Andrade et al. (2012) showed that differences in physical fitness and sports activities may imply different abilities in the development of strength, and, consequently, in the ratio Flex/Ext of the knee. For this group of athletes, the analysis of the ratio Fle/Ext is of the utmost importance since the flexors stabilize the movements during the weight lifting (Dos Santos et al., 2002) and a muscle imbalance increases the chances of injuries in the involved joint. The muscle imbalance in this group of athletes is not due to a strength deficit of the flexors, but rather to a great increase of strength in the knee extensors. The demand from the knee extensors during most of the movements on weight lifting occurs eccentrically, thus propitiating the imbalance between flexors and extensors (Stone et al., 2006; Janz et al., 2008; Storey & Smith, 2012).

**Conclusions**

Given the facts, it has become acknowledged that the muscle demands during the weight lifting are greater at slower speeds, therefore justifying higher average scores of the PT at speed of 60º/s and lower at speed of 240º/s when compared to athletes of other sports such as soccer, futsal, rugby, basketball and volleyball. Concerning the muscle imbalance between limbs, the dominance of the lower limbs played no determinant role in generating muscle imbalances between the DL and the NDL, for both knee extensors and knee flexors performance. This result as expected due to the weightlifters' athletic specialties being bilateral and symmetrical.

However, an important piece of information found in this study was the identification of muscle imbalances between knee flexors and extensors, both in DL and in NDL. It demonstrates that the flexors present average scores of PT below expected when compared to extensors, spotlighting the importance of the increase of training so that the knee flexors reach an ideal level in relation to the extensors. Furthermore, this information regarding muscle imbalances is of the upmost importance to aid the prevention of musculoskeletal injuries. The results presented in this study show that specific evaluations are essential to improve athletes' muscular performances and that isokinetic dynamometry is a tool of easy interpretation that could.

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