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Original Article

The reliability of electromechanical delay during squat jump

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Abstract:
EMD as a factor influencing the speed of muscle force production, measured during squat jump, can be used as a relevant substitution for isometric or isokinetic assessment. The purpose of this study was to examine the reliability of measurement of EMD in knee muscles (biceps femoris, semitendinosus, rectus femoris) during a vertical jump. Thirteen volunteers unfamiliar with the squat jump participated in this study and were measured 2 times, with rest periods of 7 days between measurements. EMD was calculated using a force platform and electromyography. Intraclass correlation coefficients ranged (ICC) from 0.69 to 0.78, indicating high reliability for the rectus femoris (RF) and semitendinosus (ST) and moderate reliability for the biceps femoris (BF). Absolute reliability expressed by standard error of the measure (SEM) ranged for RF 28.11, BF 23.18 and ST 21.20, better used as a coefficient of variation (CV of SEM) for RF 22.81%, BF 25.19% and ST 19.72%. These findings provide researchers and clinicians with another method for relatively fast measurement of EMD using portable devices.
Key words: reliability, electromyography, squat jump, Intraclass correlation coefficient.

Introduction

EMD is defined as the time between the onset of muscle activity and the onset of force production by muscle contraction (De Ste Croix, ElNagar, Iga, James, & Ayala, 2015; Zhou, Lawson, Morrison, & Fairweather, 1995) or as the time interval between the stimulation of the alpha motor neuron and the first recording of motion that is induced in a certain joint (Georgoulis et al., 2015). EMD might be used as an indirect measurement of muscle-tendon unit stiffness (Blackburn, Bell, Norcross, Hudson, & Engstrom, 2009). Moreover, EMD is important for energy storage in elastic components during a stretch-shortening cycle (SSC) (Georgoulis et al., 2005), and therefore might be a determinant of explosive neuromuscular performance (Tillin, Jimenez-Reyes, Pain, & Folland, 2010). Furthermore, it was suggested that the EMD in the knee joint muscles may be important for joint stabilization and determination of efficient feedback strategies that alter muscle activation in response to situations that load the anterior cruciate ligament (De Ste Croix, 2012). Longer reaction times from hamstrings may negatively affect the muscle´s ability to quickly stabilize the knee joint and therefore might increase the risk of injury (Blackburn et al., 2009).

The EMD has been measured in previous studies under maximum voluntary isometric conditions (Cé, Rampichini, Limonta, & Esposito, 2014; De Ste Croix et al., 2015; Georgoulis et al., 2005; Hannah, Minshull, Smith, & Folland, 2014; Howatson, 2010; Howatson, Glaister, Brouner, & Someren, 2009; Libardi et al., 2015; Rodrigues Ferreira, & Vencesbrito, 2012; Yavuz, Şendemir-Ürkmez, & Türker, 2010) as well as in isokinetic conditions (Cé et al., 2014; De Ste Croix et al., 2015; Georgoulis et al., 2005; Stock, Olinghouse, Mota, & Drusch, 2016). However, the use of isometric or isokinetic measurement for EMD assessment can be a time- and space-consuming as well as costly tool in research and clinical practice. An alternative might be measurement of the EMD during a vertical jump, specifically during a squat jump, which occurs in many sports. The squat jump is used to calculate the eccentric utilization ratio, which has been suggested as a useful indicator of power performance in athletes (McGuigan, Doyle, Newton, Edwards, Nimphius & Newton, 2006).

Only one reliability study on EMD measurement has been reported (Howatson et al, 2009). The reliability represented by the Intraclass correlation coefficient (ICC) of EMD in elbow flexors under isometric conditions was lower (ICC = 0.55–0.79) than under dynamic isokinetic conditions (ICC = 0.89–0.96) (Howatson, et al., 2009). To the best of our knowledge, the reliability of the EMD during a squat jump has not been reported. Therefore, the aim was to analyse the absolute and relative reliability of the EMD measured through a vertical jump in a cohort of young adults.

Materials and Methods

The screened population consisted of healthy adult university students. Thirteen volunteers participated in this study, including 6 females (22.5 ± 3.7 years; 62.0 ± 7.1 kg; 167.1 ± 3.7 cm) and 7 males (22.8 ± 2.2 years;

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80. 1 ± 8.4 kg; 182.7 ± 8.7 cm). The inclusion criteria were a minimum of 18 years of age, no previous injury of the lower extremities, and no serious disorders of the musculoskeletal or nervous system. Athletes training more than 4 times per week were excluded to eliminate large differences in strength. The study was reviewed and approved by the local university ethics committee. The day before measurement, participants avoided strenuous physical activity. The study consisted of 3 measurement sessions, conducted at the same time for each students to exclude the influence of circadian cycle, with a rest period of 7 days between sessions. Subjects performed all experimental sessions under the same environmental conditions. The first measurement was a familiarization session for the squat jump. The two subsequent testing sessions were used for the experimental measurements.

Squat jump assessment

Before squat jump assessment, participants underwent a nonspecific warmup consisting of 5 min on a stationary cycle ergometer (1.5 W/kg of body eight at a pedal rate of 70-80 RPM) and 5 min of dynamic lower extremity and trunk muscle stretching. Afterwards, 10 consecutive squat jumps with progressive knee and hip flexion and progressive effort to reach maximum jump height were performed as a specific warmup.

Squat jump assessment was performed as described by Choukou et al. (2014). The participants stood on a force platform PS-2142 (Pasco, Roseville, CA, USA) with weight evenly distributed over both feet; hands were placed on the hips throughout the test. The participants squatted down until the knees were bent to 90° between the femur and tibia and held this position for 2-3 s. After verbal instruction, the participants extended their knees and jumped vertically as high and fast as possible, landing back on the plate. No initial steps or movement were allowed before take-off. Participants jumped with their shoes on 3 times, with 1 min rest between each trial.

Surface electromyography

Surface EMG activity was recorded using 8 channels with an inter-electrode distance of 10 mm (Noraxon 1400A, Noraxon, Scottsdale, AZ, USA). The EMG was synchronized with the force platform. EMG activity was recorded from muscles in the dominant leg (step up on the chair): rectus femoris (RF), biceps femoris (BF), semitendinosus (ST) (Merletti, & Parker, 2004) because this muscles are the main in flexion and extension of the knee joint. The raw signal was collected at a frequency of 1,000 Hz and impedance of 10 MΩ. Self-adhesive, disposable 24-mm electrodes were used. In order to establish resting EMG and torque values, subjects held an initial semi-squat position for 3 s.

The EMD was defined as the time interval between the onset of EMG activity and the onset of vertical force development. Peak values of force were defined as 10% of maximum values of flight. Baseline values of force were calculated as the mean of values in the time interval from 1.0 to 1.5 s before the time of peak value. Onset of EMG activity were calculated as baseline values + 10% of the peak.

Statistical analysis

Statistical analysis was performed (Statistica version 12; StatSoft, Inc., Tulsa, OK, USA). The Shapiro-Wilks test showed non-normal data distribution for observed variables. The Friedman ANOVA test was used to detect systematic bias among three attempts during each day. As there were no significant differences between trials, the second trial from each day was used for the assessment of test-retest reliability. Relative reliability was assessed using ICCs. The ICC values were defined as very low (<0.29), low (0.30-0.049), moderate (0.50-0.69), high (0.70-0.89), and very high (>0.90) levels of reliability (Munro, 1997). Absolute reliability was assessed using the standard error of measurement (SEM) expressed by coefficient of Variance (CV). In addition, the standard deviation of mean difference was calculated. Analyses were performed for a level of significance set at $\alpha = 0.05$.

Results

Friedman ANOVA analysis, within a 5% significance, detected no statistically significant differences (Table 1) between the results obtained from the first, second and third measurements. ICC values (Table 2) ranged from 0.69 to 0.78, indicating high reliability for the rectus femoris and semitendinosus and moderate reliability for the biceps femoris.

Table 1 Friedman ANOVA analysis

Muscle	Measurement	F	p
RF	1	0,4	0,82
BF		5,93	0,05
ST		0,93	0,62
RF	2	1,71	0,42
BF		3,86	0,15
ST		2,71	0,26

Legend: RF – rectus femoris, BF – biceps femoris, ST – semitendinosus, F – f test, p – significant level p

Table 2 Reliability of electromechanical delay (ms)

Muscle	Mean 1	Mean 2	Mean	Mean difference	SD	ICC	SEM	% CV of SEM
RF	135.4	111.1	123.2	50.3	59.3	0.78	28,11	22,81
BF	99.5	84.6	92.0	49.3	41.4	0.69	23,18	25,19
ST	120.3	94.7	107.5	44.5	39.2	0.71	21,20	19,72

Legend: RF –rectus femoris, BF –biceps femoris, ST –semitendinosus, Mean 1 – group mean for the first measurement, Mean 2 – group mean for the second measurement, Mean – group mean from both measurements, SD – standard deviation, ICC – Intraclass coefficient, SEM – standard error of measurement, % CV ze SEM – coefficient of variation

Discussion

The aim of the present study was to verify reliability of the EMD during a squat jump measured on a force platform. This investigation examined the test-retest reliability of EMD of knee extensors and flexors over 7 consecutive days. This is the first investigation to report the day-to-day, within-subject variation of EMD in the dominant lower extremity biceps femoris, semitendinosus, and rectus femoris muscles; hence, these data provide a useful indication of expected individual variation.

According to results of Friedman ANOVA test the learning effect (caused by repeated performing the measurement) did not influence the results in our study.

ICC values for EMD in our study were as follows: BF 0.69, ST 0.71, and RF 0.78, indicating moderate-to-high reliability. SEM for BF was 23.2, with 21.2 for ST and 28.1 for RF. To the best of our knowledge, no previous study has analysed this parameter during a vertical jump. Therefore, it is not possible to compare our data with previous studies. However, two studies evaluated isometric contraction in knee flexors (ICC = 0.913, SEM = 6.5, CV of SEM = 6.4) and extensors (ICC = 0.497, SEM = 9.3, CV of SEM = 11.2) (Stock et al., 2016) and the second study evaluated maximum voluntary contraction in plantar flexion maintained for 3 s, with ICC = 0.97, CV of SEM = 1.1 (Longo, Cé, Rampichini, Devoto, Venturelli, Limonta, & Esposito, 2017). The lower results could be caused by standardizing conditions during isometric conditions with smaller range of movement in ankle joint and controlled movement by the device.

However, the ICC is the most frequently reported measure of relative reliability in the current literature (Delvecchio, Borges, Reaburn, & Korhonen, 2016; Christos, Lachlan, & Dale, 2014). The ICC is influenced by data heteroscedacity (Hopkins, Schabort, & Hawley, 2001), because a good relationship between variables does not necessarily imply agreement or reproducibility (Deighan, De Ste Criox, & Armstrong, 2003). Nevertheless, with implementation of strict conditions during data collection using similar methodology, e.g., testing at the same time of day and use of a standardized warmup and testing protocol with the same examiner, EMD provides reliable and valid results that can form the basis of informed experimental enquiry. These data have important implications for both experimental research and clinical practice, and provide an indication of the magnitude of change that is required to elucidate a meaningful change in muscle function at the knee joint.

In summary, EMD measurement during a squat jump with strict adherence to standardized testing conditions yielded moderate-to-high levels of reliability in the knee muscles over 7 consecutive days. The results of this study on reliability of EMD measurement during a squat jump suggest possible use of this method as a relevant substitution for isometric or isokinetic assessment, with advantages such as portability and reduction of the time of measurement. According to the results of the Friedman test, there are recommendations to do more than three times, and it would be appropriate to include more subjects to analyse the absolute and relative reliability.

Conclusions

Our results showed moderate-to-high levels of reliability for EMD in 3 knee muscles during a squat jump. However further research is necessary to determine the relationship of EMD level during squat jump conditions with joint stabilization and efficient feedback strategies.

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