



Electromyographic activity during one-legged squatting under different foot positions

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ABSTRACT

The specific aim of this study was to quantify muscle activity while performing squat with technique variations. Eight healthy volunteers performed squats under 5 types of foot positions: neutral position, under a 10° descending wedge, under a 10° ascending wedge, under a 10° medial wedge and under a 10° lateral wedge. It was evaluated electromyographic data of vastus medialis oblique, vastus lateralis, rectus femoris, biceps femoris, lateral gastrocnemius and tibialis anterior muscles, using One-Way ANOVA. The EMG integrated values was not significantly different across the 5 foot positions. The results of this study suggest that different foot positions during one-legged squat do not cause changes in muscle recruitment.

INTRODUCTION

Squat exercises have been widely used in the last years in training and rehabilitation programs of the lower limb. The application of variations of this exercise with the aim to observe different patterns of muscular activity, has been very usual⁽¹⁻⁷⁾. The understanding of the pattern of the muscular activity during squat may increase the selection of prevention, rehabilitation and sports training programs of the lower limb⁽⁸⁾.

The use of orthoses⁽⁶⁾, different situations^(2,4,7) and feet stances⁽³⁾, as well as the application of different degrees of rotation of the lower extremity^(1,4-5) were some of the strategies used in order to trigger selective muscular recruitment during squat.

During single-legged squat, the electromyographic behavior of the quadriceps musculature was studied associated to different foot stances in the medium-lateral direction⁽³⁾. In this study, no differences were observed in the electromyographic behavior (EMG) of two uniarticular units⁽³⁾: vastus medialis oblique and vastus lateralis muscles. On the other hand, Hertel *et al.*⁽⁶⁾ found differences in the EMG activity pattern in this very task using an orthosis for correction of foot pronation and supination. Nevertheless, the trunk positioning and the angular velocity of the knee were not controlled in any of these studies, which could influence the muscular recruitment pattern⁽⁹⁻¹²⁾.

We hypothesize that with the control of the angular velocity of the knee and the sagittal and frontal trunk dislocation, we could observe a different muscular activity pattern during the single-legged squat associated to different foot stances on the medium-lateral and antero-posterior positions.

Since single-legged squat is frequently applied in rehabilitation activities⁽¹³⁻¹⁴⁾ and in tests used in the pre-participation physical exams⁽¹⁵⁻¹⁶⁾, this study may contribute for the understanding of this task, besides aiding in the elaboration of rehabilitation programs.

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Thus, the aim of the present study was to quantify the muscular activity during single-legged squats with variations in the technique and with control of 2 kinematic parameters –angular velocity of the knee and trunk dislocation.

METHODOLOGY

Subjects

Eight healthy and right-handed subjects (four male, four female) age range 18-24 years participated in the study. The medical history of all subjects was evaluated and later the ones who did not present any organic deficiency, surgery or back/lower limbs pain were selected. The descriptive statistics of these subjects is found in table 1.

TABLE 1
Descriptive statistics for men (n = 4), women (n = 4) and total sample (n = 8)*

	Age (years)	Height (cm)	Weight (Kg)
Men	19.7 ± 1.0	1.7 ± 0.0	69.6 ± 0.9
Women	22.7 ± 0.7	1.6 ± 0.0	54.7 ± 1.8
Total sample	21.2 ± 0.8	1.6 ± 0.0	62.1 ± 2.97

* Values expressed as mean ± EPM.

Prior to the experiment, all subjects read and signed a clarified consent form approved by the Committee of Ethics in Research of the Ribeirão Preto University.

Instruments

Registration of the electromyographic data (EMG)

Prior to the data collection, the site of each electrode was shaved and cleaned with alcohol in order to facilitate its adherence as well as the conduction of EMG signals. Bipolar surface electrodes (10 x 1 mm) DeSYS (model DE2.2L) were positioned with a 3 cm distance between them. The procedures described by Bevilaqua-Grosi *et al.*⁽¹⁷⁾ were followed for the electrodes placement on the vastus medialis oblique muscle (VMO). For the straight femoral (SF), vastus lateralis (VL), biceps femoral (BF), gastrocnemius lateralis (GL) and anterior tibialis (AT), the electrodes were placed according to the procedures applied by Basmajian and Blumenstein⁽¹⁸⁾. In all collections, the site was identified and prepared by the same researcher. The EMG signals were amplified (x 2000), filtered (*band pass* 20-450 Hz) and registered. The data were digitalized at 12 bits, collected by an IBM-PC computer at 1000 Hz and expressed in millivolts (mV). The EMG signals were not normalized since the comparisons are done within the same muscle, and not between different muscles.

Registration of the kinematic data

For the analysis of the movements, the X, Y and Z coordinates were registered with the aid of LEDs (*Light Emission Diodes*) which

were attached to the center of the shoulder, hip, knee and ankle joints (lateral extremity of the acromio; femoral major trochanter; femoral lateral epicondyle and lateral malleolus) (figure 1). The infrared signal emission of these points was with 100 Hz frequency by a tridimensional optical system OPTOTRAK 3020.

Data processing

The electromyographic signals (EMG) and the registrations of the X, Y and Z points were synchronized by a ODAU II – *Optotrak Dates Acquisition Unit II* synchronizer and later mathematically treated by a code in *MatLab (Math Works Inc., version 6.0)*. The linear dislocation of the points, the dislocation of the knee and angular velocity were calculated in this code. Moreover, the EMG signals of each muscle were quantified. All squat tasks which had linear dislocation longer than three centimeters in the antero-posterior and latero-lateral positions were discarded with the purpose to reduce the interferences derived from each subject's balance. The linear dislocation of the mark on the acromio was used as reference for the performance of this procedure.

The electromyographic signals were calculated in the descending phase of the squat, using as reference for the calculation the angular velocity of the knee. The beginning of the movement was considered when the initial velocity reached 5% of the velocity peak and the end of the movement when the final velocity reached 5% of the velocity peak. During the movement two phases were considered (acceleration and desacceleration). The acceleration phase was considered between the beginning of the movement and the velocity peak and the desacceleration phase was considered between the velocity peak and the end of the movement.

The velocity of the knee was used for the quantification of the electromyographic signals of the vastus medialis oblique (VMO); straight femoral (SF), vastus lateralis (VL); biceps femoral (BF); gastrocnemius lateralis (GL) and anterior tibial (AT) muscles. The electromyographic signals (EMG) were integrated in the acceleration and desacceleration phases of the movement. Mean of the EMG of each muscle was calculated for each kind of squat for each subject.

Data analysis

All data used in the statistical analysis were submitted to the Kolmogorov-Smirnov test in order to verify whether they presented a normal distribution. All analyzed data presented normal distribution. The one-way (ANOVA) variance analysis was used in order to individually test the effect of the type of squat over the electromyographic signal of each muscle. The same analysis was applied for the comparison of dislocation, angular velocity of the knee and trunk dislocation in the different types of squat. In all evaluations the significance level considered was lower or equal to 5% ($p \leq 0.05$).

RESULTS

Dislocation and angular velocity

The breadth of the angular dislocation of the knee and the knee joint angular velocity were not statistically different (table 2) in the five types of squats performed in different foot stances (NP; PF; DF; S and P). The values of the angular dislocation are expressed in figure 2.

Electromyographic analysis

The statistical analysis did not show effect of the different types of single-legged squat over the electromyographic activity (EMG) of the muscles analyzed in the acceleration and desacceleration phases (table 3). The EMG of the analyzed muscles in the acceler-

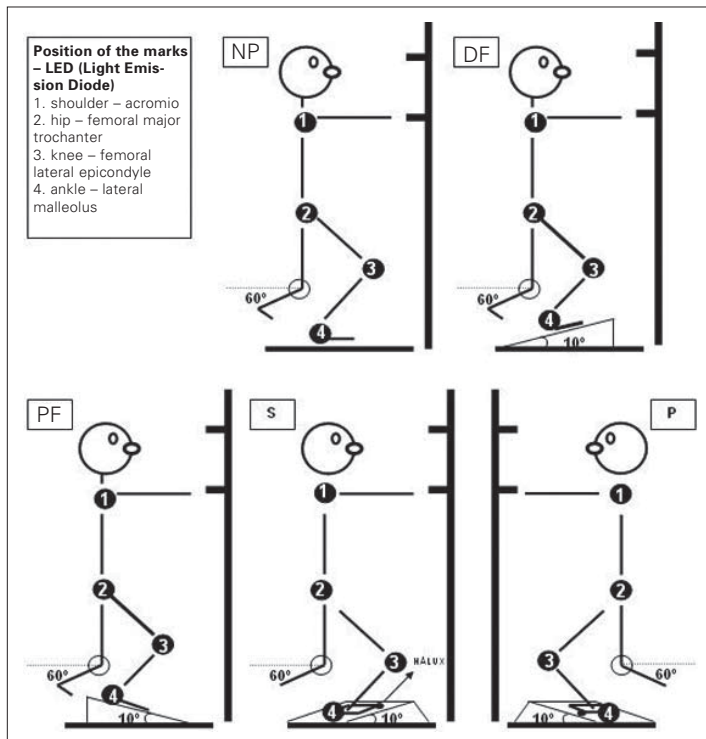


Figure 1 – Graphic representation of the stances of the individuals after single-legged squat. NP = neutral position; DF = dorsal flexion; PF = plantar flexion; S = supination; P = pronation.

Procedure

Single-legged squat with foot on Neutral Position (NP)

Each subject was placed standing, with the right limb on the center of a square (80 x 80 cm) drawn on the ground. Each participant was asked to keep the left knee flexed approximately 60°. The subject kept the right knee in total extension and the upper limbs extended and raised to the front with a 90° shoulder flexion angle. A glass board was placed in the front of the participant with marks setting the targets. These marks would delimit the initial and final positions of the movement and represent a breadth of 35° to 40° of knee flexion, having as reference the arm dislocation. From the initial position, when receiving the verbal command, the subject performed the single-legged squat by knee flexion. The subjects were motivated to perform each movement the fastest as possible. When reaching the target, the subject would keep the position until receiving another verbal command to return to the initial position. Only the descending phase of the squat was analyzed. A series of 10 squats was performed. Figure 1 represents the graphic form of the single-legged squat with foot in neutral position.

Single-legged squats with foot on Plantar Flexion (PF); Dorsal Flexion (DF), Supination (S) and Pronation (P) stances

For the performance of right foot squats in the PF, DF, S and P positions the same procedure described above was performed, associated with the use of a wooden platform (55 x 55 cm). This platform with 10° inclination was set in order to position the foot in 10° of PF; 10° of DF; 10° of S and 10° of P prior to the beginning of the squat. The choice of a platform with 10° inclination was based on the study by Hung and Gross⁽³⁾. Figure 1 graphic represents the single-legged squat with the foot on plantar flexion.

TABLE 2
(ANOVA) variance analysis – Kinematic parameters

	F	Freedom degrees	p
Angular dislocation of the knee	1.27	(4, 28)	< 0.30
Angular velocity of the knee	0.85	(4, 28)	< 0.50

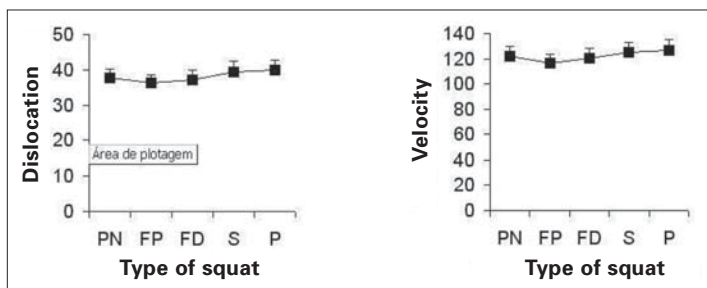


Figure 2 – Dislocation and angular velocity of the knee joint during the different types of single-legged squat. All values were expressed by means and standard error.

TABLE 3
(ANOVA) variance analysis – Electromyographic activity (EMG) in the acceleration (AP) and desacceleration phases (DP)

Muscles (FA)	F	Freedom degrees	p	Muscles (DF)	F	Freedom degrees	p
VMO	2.09	(4, 28)	< 0.10	VMO	1.33	(4, 28)	< 0.28
SF	1.24	(4, 28)	< 0.31	SF	0.61	(4, 28)	< 0.65
VL	2.18	(4, 28)	< 0.09	VL	1.41	(4, 28)	< 0.25
BF	1.11	(4, 28)	< 0.37	BF	0.14	(4, 28)	< 0.96
GL	1.28	(4, 28)	< 0.30	GL	1.19	(4, 28)	< 0.33
AT	4.59	(4, 28)	< 0.50	AT	1.61	(4, 28)	< 0.20

ation and desacceleration phases of the single-legged squat is represented in figure 3.

DISCUSSION

The outlining of the study was mainly directed in order to provide information concerning the influence of foot stances over the electromyographic activity of uniaxial and biaxial muscles during single-legged squat. Single-legged squat is a task of complex weight discharge where several muscles act together.⁽¹⁶⁾ Moreover, single-legged squat is a task applied in the rehabilitation of the muscle-skeletal system⁽¹³⁾ and is related to sports activities; being important to athletes' dribbling, jumping and balancing⁽¹⁵⁾. It has been more recently suggested that such task, if performed with the foot positioned in 25-degree decline, could be beneficial to subjects recovering from patellar tendinopathy⁽¹⁴⁾.

Despite the relevance of the single-legged squat in the athletic and rehabilitation activities, few works investigated the electromyographic behavior of the main muscles involved in the single-legged squat. Hung and Gross⁽³⁾ investigated the influence of the foot medial and lateral inclination over the EMG activity during single-legged squat. They did not find difference in the vastus medialis oblique and vastus lateralis ratio, using a 10° board for foot inclination⁽³⁾. These results are contrary to the ones observed by Hertel *et al.*⁽⁶⁾ who found an increase in the EMG activity of the vastus medialis and the gluteus medius during the squat with utilization of orthoses for correction of the turn-out in the medium-lateral position. These authors⁽⁶⁾ did not observe correlation with the orthosis inclination position, that is, regardless the postural correction, the use of the orthosis determined increase of the electromyographic activity of the vastus medialis and the gluteus medius.

Our results did not show differences in the EMG activity during the tasks proposed, corroborating thus the results by Hung and Gross⁽³⁾. The difference may be given to the fact that in our studies a 10° platform was used, which caused alterations of the foot stances as a whole, while Hertel *et al.*⁽⁶⁾ used an orthosis only on the back of the foot (inside the shoe) which caused a local alteration of one region of the foot. Besides that, differences in the task performance where Hertel *et al.*⁽⁶⁾ did not control the trunk position or the angular velocity of the knee, could have influenced the results.

Richardson and Bullock⁽⁹⁾ verified that the increase of the flexion-extension movement of the knee caused the EMG activity of the straight femoral and the hamstrings to increase, while the EMG activity of the vastus medialis and the vastus lateralis did not suffer alteration. Hagood *et al.*⁽¹⁰⁾ find a great increase of the EMG activity antagonist of the quadriceps and hamstrings applying an increase of the joint velocity of the knee. In our study we monitored the angular velocity of the knee in the five types of performed squat, except for the influence of velocity over the EMG. According to Henry *et al.*⁽¹¹⁾ the EMG activity of the thigh muscles is influenced by postural dislocations in the lateral and antero-posterior direction. Within this context, another study⁽¹²⁾ verified EMG alterations of the soleum muscle during squats performance over unsteady surface. These authors also related the EMG alterations of the soleum to its role in the postural control. We also performed the control of the trunk dislocation with the aim to decrease the effect of the postural control over the EMG.

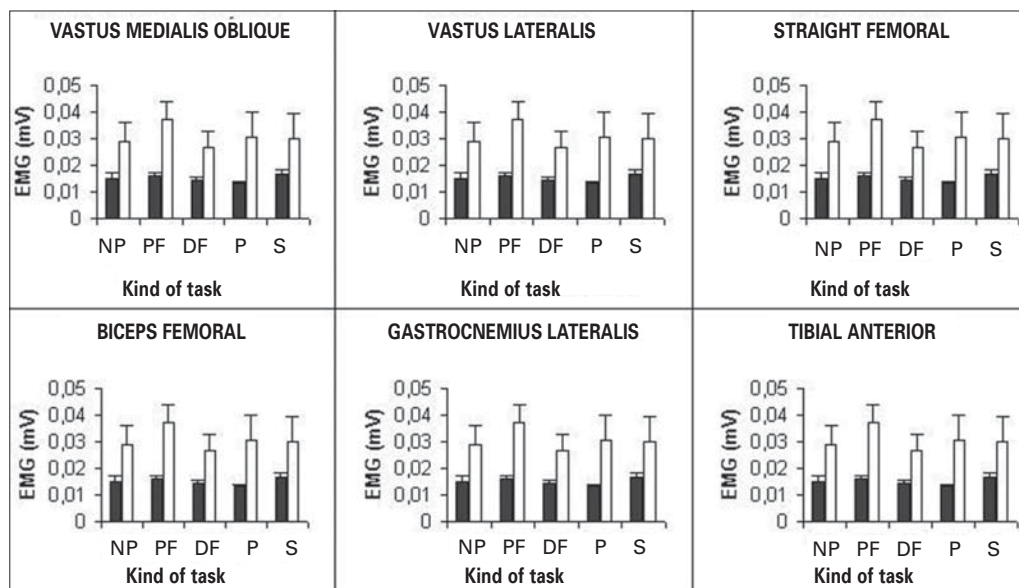


Figure 3 – Electromyographic activity (EMG) of the muscles analyzed during the different types of single-legged squat. The black bars represent the EMG in the acceleration phase and the white bars the EMG in the desacceleration phase of the movement. All values were expressed by means and Standard error.

Clinically speaking, a protocol applying single-legged squat exercises associated to the foot stances on a platform with 25° inclination was able to cause clinical improvement in athletes with patellar tendinopathy⁽¹¹⁾. Compared with our study, this higher inclination (25°) kept the ankle in plantar flexion, which could favor a different muscular recruitment pattern of the quadriceps, justifying thus the improvement of the inflammation. Further studies exploring the kinematic, kinetic and electromyographic behavior are needed in order to understand the positive results in the patellar tendinopathic treatment.

CONCLUSION

Our results suggest that alterations in foot stance during single-legged squat, according to the described methodology, do not cause alterations in the muscular recruitment pattern of the main muscles involved in the task.

All the authors declared there is not any potential conflict of interests regarding this article.

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