ELECTROMYOGRAPHIC ACTIVITY AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION DURING NEUROMUSCULAR EXERCISES

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The aim of this study was to compare the muscular activity of knee stabilizers in different neuromuscular exercises in individuals with ACL reconstruction and nonlesioned individuals. Eight males submitted to ACL reconstruction and eight nonlesioned males participated. The maximum voluntary isometric contraction (MVIC) of each muscle was used for signal normalization. The electromyographic signal was quantified by the root mean square. The MVIC % between groups was different for extensor muscles of the nonlesioned group, when compared to flexor muscles of the reconstructed group.

KEY WORDS: Electromyography, ACL, Physical therapy techniques, Proprioception.

INTRODUCTION:

The anterior cruciate ligament (ACL) is one of most studied structures in biomechanics and rehabilitation. Its function is to provide tibialis anterior stability in relation to the femur and orient knee flexion and extension. Moreover, it limits knee hyperextension, performs constraint mechanisms and controls valgus and varus stress (Houck *et al*., 2005). In the USA, about 60.000 individuals with ACL injury are annually submitted to reconstruction surgery (Daniel *et al*., 1994).
After ACL injury, functional deficits and joint instability occur. Secondarily, proprioception is affected by the loss of ligament mechanoreceptors. This loss can determine joint position sense reduction, leading to the aggravation of these dysfunctions (Barrett, 1991). The treatment goal after ACL reconstruction is to facilitate a return to functional activities through adequate programs that contain the following approaches: muscular force, flexibility, endurance, and neuromuscular reeducation. Moreover, protection of the reconstructed joint, a reduction in complications and the prevention of recurrences are also indicated (Feller *et al*., 2002). Neuromuscular reeducation training may enhance control of abnormal joint translation during functional activities by inducing compensatory alterations in muscle activity patterns (Risberg *et al*., 2001). The goal of this study was to compare the electric activity of the muscles that stabilize the knee in different neuromuscular exercises of individuals presenting ACL reconstruction and nonlesioned individuals.

METHOD:

Subjects: Eight males (aged $\bar{x}$ = 31.8 ±7.0 years-old), submitted for ACL reconstruction (by central third patellar tendon autograft) more than 30 months prior to the study ($\bar{x}$ = 34.8 ±13.7 months) and eight nonlesioned males (control group) (age $\bar{x}$ = 32.0 ±7.3 years-old) participated in the study. Individuals presenting pain or swelling in the knee were excluded.

Instrumentation and Procedure: The functional status of the subjects was assessed by the Single Hop for Distance test (Noyes *et al* 1991) and the Lysholm questionnaire (Peccin *et al*. 2006). An eight channel surface EMG system was used (EMG System do Brazil) to record the EMG signals. All raw EMG signals were bandpass filtered between 10 and 500 Hz, amplified (common mode rejection ratio >100 dB, overall gain 1000, noise <1 IV RMS) and analogue-to-digital converted (12-bit) at a sampling rate of 2000 Hz. The maximum voluntary isometric contraction (MVIC) of each muscle (vastus medialis obliquus (VMO), vastus lateralis (VL), semitendinosus, biceps femoris and medial gastrocnemius) was measured. After electrode positioning according to the SENIAM project, the neuromuscular exercise

order was randomized in such a way as to prevent bias due to individuals arriving fatigued at the last device. Participants were permitted a short training session prior to data collection.
One minute of electromyographic signal was collected, with the first and last ten seconds being discarded. It was understood that the forty remaining seconds are a reliable assessment of the muscular activity of neuromuscular training. The following devices were used (all in unipodal support and with 30° knee flexion) for the neuromuscular exercises: unipodal support on the ground, inclined plate, round plate, *balancin*, anterior-posterior and medium-lateral rollerboard direction.
The electromyographic signal was quantified by the root mean square (RMS), and normalized by the MVIC values.

Statistical analysis: The Student *t* test was used to analyze the demographic variables, since data estimates permitted its use.
For the MVIC % values between groups, multivariate analysis of variance was used (MANOVA). For this, the homogeneity matrices and F test were first analyzed to verify differences between groups. Post-hoc was realized using the Bonferroni test. Significance was adopted at 5%.

RESULTS:

The demographic and morphological data of the individuals evaluated, with and without ACL injury, are presented in Table 1. No significant statistical difference in age or body mass was found between the groups.

Table 1. Morphological and Demographic Data

	Recontruction group (n = 8)		**Control group (n = 8)**	
	$\bar{x}$ **(SD)**	**Min - Max**	$\bar{x}$ **(SD)**	**Min - Max**
Age (years)	31.8 (7.0)	20.0 - 40.0	32.0 (7.3)	20.0 - 40.0
Body Mass (kg)	79.2 (12.6)	57.0 - 94.3	84.5 (12.2)	63.0 - 100.0
Height (m)	1.74 (0.11)	1.61 - 1.93	1.81 (0.06)	1.69 - 1.87

It was found a difference when compared extensor muscles of the control group when compared to flexor muscles of the reconstructed group for the same neuromuscular device (VMO or VL muscles of the control group in relation to the semitendinosus or biceps femoris of the reconstructed group). These differences appeared when the inclined plate (Table 2), round plate (Table 3), *balancin* (Table 4) and anterior-posterior rollerboard (Table 5) exercises were realized. During unipodal support on the ground and medium-lateral rollerboard direction no significant differences were found. In this type of comparison, the gastrocnemius muscle presented no significant difference in any device.

Table 2 - Mean ($\bar{x}$) and Standard Deviation (SD) of MVIC % for inclined plate

<table>
<tr><th></th><th></th><th colspan="2">Control Group</th></tr>
<tr><th></th><th></th><th>Vastus medialis obliquus
$\bar{x}$ = 83.1; SD = 21.5</th><th>Vastus Lateralis
$\bar{x}$ = 82.5 ; SD = 17.0</th></tr>
<tr><td rowspan="2">Reconstructed group</td><td>Biceps Femoris
$\bar{x}$ = 11.7; SD = 4.6</td><td>P = 0,026</td><td>P = 0,029</td></tr>
<tr><td>Semitendinosus
$\bar{x}$ = 18.7; SD = 9.4</td><td>P = 0,001</td><td>P = 0,001</td></tr>
</table>

Table 3 - Mean ($\bar{x}$) and Standard Deviation (SD) of MVIC % for round plate

		Control Group	
		Vastus medialis obliquus $\bar{x}$ = 87.7; SD 18.3	**Vastus Lateralis** $\bar{x}$ = 89.5 SD = 15.6
Reconstructed group	**Biceps Femoris** $\bar{x}$ = 22.1; SD =5.7	*P* = 0,009	*P* = 0,006
	Semitendinosus $\bar{x}$ = 38.7; SD =12.7	*P* = 0,001	*P* = 0,001

Table 4 - Mean ($\bar{x}$) and Standard Deviation (SD) of MVIC % for *Balancin*

		Control Group	
		Vastus medialis obliquus $\bar{x}$ = 85.9; SD = 14.4	**Vastus Lateralis** $\bar{x}$ = 87.8 SD = 15.3
Reconstructed group	**Biceps Femoris** $\bar{x}$ = 18.0; SD = 7.5	*P* = 0,016	*P* = 0,001
	Semitendinosus $\bar{x}$ = 21.1; SD = 9.5	*P* = 0,028	*P* = 0,001

Table 5 - Mean ($\bar{x}$) and Standard Deviation (SD) of MVIC % for anterior-posterior rollerboard

		Control Group	
		Vastus medialis obliquus $\bar{x}$ = 77.5; SD = 13.3	**Vastus Lateralis** x = 77.5; SD = 13.3
Reconstructed group	**Biceps Femoris** $\bar{x}$ = 17.0; SD = 7.0	*P* = 0,019	*P* = 0,011
	Semitendinosus $\bar{x}$ = 24.7; SD = 10.1	*P* = 0,001	*P* = 0,001

DISCUSSION:

The initial hypothesis was that muscle electrical activities in different neuromuscular training exercises were equal when comparing individuals with surgical ligament reconstruction and the control group. Given the results, this hypothesis can only be rejected for the extensor muscles of the control group, when compared to the flexor muscle of the ligament reconstruction group. This could indicate a deficit of cocontraction between the flexor and extensor muscles. Fonseca *et al*. (2004) evaluate individuals presenting knee ligament injury without reconstruction submitted to conservative treatment while performing some neuromuscular exercise and suggest this co contraction.

In the present study, RMS values were collected for 40 seconds, with minimal previous training. It is possible that after a single training program these values could be different. Barret *et al*. (1991) disclosed that knees with ACL injury presented proprioception deficits when compared to normal knees, however when the same authors analyzed a group that underwent ligament reconstruction and three months of neuromuscular training, they obtained results similar to a nonlesioned group.

A review by Risberg *et al.* (2004) show that neuromuscular exercises present promising results; however, studies analyzing specific exercises are rare.

When ligament reconstruction group muscles were analyzed, minor activation was verified during neuromuscular exercises when compared to the control group, indicating a recruitment deficit to perform exercises after a long postoperative period. This also occurred in a study by Fonseca *et al*. (2004), despite the difference in the sample evaluated, indicating a continued muscular recruitment necessity over a long period. Thus, it would seem that muscular balance is reached independent of the presence or absence of ligament surgery reconstruction.

Some authors investigated muscles adaptations after an ACL injury without reconstruction during closed kinetic chain exercises (Fitzgerald *et al* 2000). With the results of our study, reconstruction could also have caused some of these adaptations, such as imperfection in muscle cocontraction during neuromuscular exercises after ACL ligament reconstruction. Moreover, a global reduction motor recruitment in the post operated leg was found in relation to the control group. This result is in agreement with Heller and Pincivero (2003), regarding low activity in hamstrings, however they use different devices in comparison with this present study.

CONCLUSION:

In specific acute neuromuscular exercises, differences were observed when control group extensor muscles were compared to flexor muscles of the ACL reconstructed group when performing inclined, round plate, *balancin* and anterior-posterior roller-board. This could suggest a co contraction deficit even after an ACL reconstruction.

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