

ACUTE EFFECT OF QUADRICEPS STRETCHING ON VERTICAL GROUND REACTION FORCE, MUSCLE ACTIVITY AND VERTICAL JUMP PERFORMANCE

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The aim of this study was to analyze the acute effects of stretching on jumping performance (vertical velocity of the center of mass), vertical ground reaction force (peak force and rate of force development) and electromyography (EMG) of the vastus lateralis (VL) during the countermovement jump (CMJ). Nineteen male individuals performed the CMJ test before and after one quadriceps stretching session. This session consisted of four 20-second repetitions of passive static stretching of quadriceps. The results indicated a significant reduction in the rate of force development, a reduction in the integrated EMG during the eccentric phase and an increase in duration of the concentric phase. However, these alterations did not affect the vertical jump performance.

KEY WORDS: stretching, performance, EMG, counter movement jump.

INTRODUCTION: Previous studies have demonstrated a negative acute effect of stretching exercises on muscle force output (Weir *et al.*, 2005). Among the possible explanations for reduction in maximal strength are changes in motor neuron excitation states and decreases in the stiffness of muscle-tendon units (MTU) caused by stretching. However, training loads used on researches do not reflect the reality of flexibility training within the sports field. In addition, the measurement of maximal strength did not consider the sport-specific factors. This aspect may lead to the question about transferring these results to the motor demands with different movement patterns as well as muscle actions.

Using training loads closer to the ones used in sports practice, some studies determined the effect of flexibility training on performance during countermovement jumps (CMJs) that led to different results. Power *et al.* (2004), Unick *et al.* (2005) and Knudson *et al.* (2001) did not show performance changes, but Wallmann *et al.* (2005) and Cornwell *et al.* (2002) observed a significant decrease in the jump height, calculated using the ground reaction force.

However, none of these studies determined the peak of force. In addition, the Cornwell *et al.* (2002) study used a single joint task for strength testing and did not reflect the complex movements made during sports practice. Changes in muscle activity of the triceps surae caused by stretching have been investigated (Wallmann *et al.*, 2005; Cornwell *et al.*, 2002), however, information about the effects of stretching exercises on EMG of the vastus lateralis during the CMJ is still rare.

The present study aims to analyze the acute effect of stretching quadriceps femoris muscles on the vertical ground reaction force, muscle activity and vertical jump performance.

METHODS:

Study design: Nineteen male physical education students participated in this research (age, 23,7 ± 2,3 years; body mass, 72,6 ± 7,1 kg; height, 176,0 ± 7,0 cm). All subjects performed two jumps using the CMJ technique in two situations: a) before (pre-test) and after (post-test) a session of passive static stretching of the quadriceps muscle (experimental protocol) and b) before and after a rest interval (control protocol). The best jump was used for statistical analysis.

The experimental and control protocols were separated by an interval of 24 hours and a counterbalance procedure was used to determine the order of protocols. During the two weeks preceding the data collection, the subjects performed five training sessions to familiarize with the CMJ technique.

Data collection :

Measurement of ground reaction force: To register the vertical ground reaction force, it was used a force platform model AMTI OR6-7, with acquisition frequency of 1KHz. The force-time (F-t) curve was recorded with the software SIMI Motion 7.2 and analyzed using the software DasyLab 4.0. The A/D converter used was the Data Translation DT9800-EC. The parameters peak of force (PF) and rate of force development (RFD) were extracted from the F-t curve. The RFD was defined as the greatest amplitude of the first differential of the F-t signal (Sale, 1991). The vertical velocity of the center of gravity (Vcg) was defined from the impulse (I) obtained from the F-t curve. The CMJ performance was characterized by the parameter Vcg.

Electromyography (EMG): EMG of the vastus lateralis muscle was collected at 1000 Hz using active bipolar surface EMG electrodes (type Ag/AgCl – Midi-Trace® 200 Foam) with 3 cm inter-electrode distance. The electrodes positioning and the preparation of the skin have been done in accordance with Cram et al. (1998). The raw signals were amplified (1000 times), filtered (4th Butterworth filter, 16-310 Hz) and full-wave rectified (LaPier et al., 2000). The duration of the eccentric and concentric phases (TECC, TCON) of the CMJ was defined from the F-t curve. The integrated value (mV.s) was calculated separately for the eccentric and concentric phases and was normalized by the duration of each phase (EMGECC, EMGCON). The data was analysed using the software DasyLab 4.0.

Flexibility assessment: The active-knee-flexion (AKF) test was used to determine quadriceps muscle group length. The quadriceps length was indirectly determined by measuring the AKF range of motion (ROM). The subjects were positioned facing down on the testing apparatus (bench for quadriceps stretching-BQS) and a Leighton flexometer (model 01146) was attached on the ankle joint of the lower leg. The positioning of the subjects in the BQS minimized the compensating movements of the pelvis (anterior pelvic tilt). The contralateral thigh was maintained against the BQS, with the hip at 90° of flexion and a pelvic stabilizer was adjusted on the pelvic region. The AKF test started from an initial position of 90° of knee flexion and the subject made an active knee flexion slowly until it reached the maximum ROM which should be kept for approximately 2 seconds. The average of the three trials was calculated to analyze the data. The intra-session reliability of the procedure was determined using an intraclass correlation coefficient (ICC). It yields an ICC of $r = 0,96$.



Fig.1A



Fig.1B

Figure 1: Initial position (A) and final position (B) of the AKF test.

The stretching exercise was made using the BQS and the positioning was the same adopted during the flexibility measurement. The passive static stretching session consisted of four sets of 20 seconds with 20-second rest interval between each set.

Statistical Analysis: Paired Student's *t*-tests were used to determine whether differences existed between the pre-test and post-test for each protocol (experimental and control) for

the measured variables. The significance for this study was accepted at the 0.05 level of probability and the statistical package used was the SPSS for Windows, version 11.0.

RESULTS: The flexibility training resulted in a significant gain score of approximately 6° in the active knee flexion ROM for experimental protocol (pre-test = 31,8° ± 10,1; post-test = 37,7° ± 9,5).

The descriptive statistics of the examined variables in both protocols (means ± SD) are presented in table 1.

Table 1 Values (Means±SD) of the different parameters for experimental and control protocols.

Parameters	experimental		control	
	pre	post	pre	post
Vcg (m.s ⁻¹)	2,48 ± 0,18	2,47 ± 0,25	2,48 ± 0,19	2,53 ± 0,37
I (N.s)	184,4 ± 20,1	183,9 ± 24,0	186,0 ± 25,0	187,1 ± 26,3
PF (N)	1062,3 ± 132,0	1022,6 ± 195,4	1070,8 ± 186,2	1030,8 ± 187,2*
RFD (N.s ⁻¹)	12159,9 ± 3789,0	10211,7 ± 2420,7*	11271,6 ± 5202,8	12348,7 ± 6143,0
T _{ECC} (ms)	509 ± 57	530 ± 70	519 ± 50	505 ± 64
T _{CON} (ms)	287 ± 27	297 ± 29*	295 ± 31	301 ± 31
EMG _{ECC} (mV)	417 ± 105	380 ± 82*	410 ± 82	385 ± 112
EMG _{CON} (mV)	1112 ± 313	1081 ± 260	1013 ± 252	1070 ± 303

* Significant difference between pre and post intervention (p < 0,05).

DISCUSSION: The significant statistical increase of ROM verified in this study indicated that the training load used was sufficient to provoke an alteration on the flexibility performance. However, this change of quadriceps stretching level did not alter the CMJ performance (Vcg). The Vcg variable which is determining the jump height and the impulse (I), used to calculate the Vcg, did not alter. This result is similar to the effect of stretching on jump performance reported by others (Knudson *et al.*, 2001; Power *et al.*, 2004; Unick *et al.*, 2005). However, only the study from Knudson *et al.* (2001) analysed the jump performance using the Vcg method. In relation to Power *et al.* (2004) and Unick *et al.* (2005), the elevation of the centre of gravity, was the selected parameter to characterize the jump performance. The maintenance of the CMJ performance after the stretching exercise is in contrast to the data presented in previous researches. Wallmann *et al.* (2005) and Cornwell *et al.* (2002) reported a significant statistical reduction of 5,6 and 7,4%, respectively, on the jump height using the CMJ. Despite of using flexibility training loads and stretching technique close to the ones presented in this study, the stretched muscle group was different (triceps surae). This methodological variation might have caused different results.

The present study investigated variables related to the muscle strength output (PF; RFD), which were not analyzed previously in other studies during the CMJ. There was a significant reduction in the RFD and no significant change in the PF after the stretching exercises. In this study, the PF corresponded to the peak of force in curve F-t during the CMJ while in other studies, the same variable was determined by utilizing single joint tests and isometric tests and was verified a reduction in the maximum force (Weir *et al.*, 2005; McBride *et al.*, 2005). It suggests that the mechanisms responsible for the muscle strength output can be differently modulated, depending on the characteristics of the strength task. The decrease of RFD did not influence the CMJ performance. One possible explanation for this result is associated with the increase of the time on the concentric phase, which might have contributed to the maintenance of the impulse and consequently of the Vcg. In addition, McBride *et al.* (2005) suggested that the potential negative influence of stretching on force output could be compensated by not stretched muscles in multiple joint activities.

In this study, it was observed a decrease of the EMG_{ECC}, indicating a reduction of the motor units recruitment. This reduction could have contributed to the decrease of RFD, however, it

did not induce any change of PF. We are unable to offer reasons for the significant difference in PF values between pre-test and post-test in the control protocol.

CONCLUSIONS: In summary, one session of stretching exercise reduced the rate of force development, the electromyographic activity on the eccentric phase and increased the duration of the concentric phase. However, these modifications did not alter the CMJ performance. Although some studies indicate an exclusion of stretching exercises before activities in which maximal strength is necessary, this decision seems to be premature concerning multiple joint movements. It is still necessary that other studies using the same methods are being made. The resulting effects of stretching several other muscular groups using the investigated variables still remain unknown.

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