THE EFFECT OF STATIC STRETCHING ON MAXIMAL VOLUNTARY CONTRACTION AND FORCE-TIME CURVE CHARACTERISTICS

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The purpose of this study was to examine the effect of static stretching of the lower limbs on maximal voluntary contraction (MVC) and isometric force-time curve characteristics (IFTC) of leg extensor muscles and integrated electromyographic activity of rectus femoris (EMGRF), biceps femoris (EMGBF) and gastrocnemius (EMGGS) muscles. Ten healthy physical education students were tested for MVC, IFTC, and EMG activity of the above muscles after a jogging and a jogging/stretch protocol of the lower limbs. There were no significant changes in MVC, IFTC, EMGBF, and EMGGS between jogging and jogging/stretch measurements. A significant decrease was observed in EMGRF. The results of this study indicated that a moderate volume of static stretching of the lower limbs did not impact significantly the majority of the variables examined.

KEY WORDS*:* isometric force, flexibility, EMG activity

INTRODUCTION: Recent investigators have reported that acute and prolonged stretching may reduce athletic performance through decrements in strength, power, vertical jump, and sprint performance (Nelson et al., 2005; Power et al., 2004; Young et al., 2001). In addition, studies have reported conflicting results on the effect of a variety of stretching routines on maximal voluntary contraction (MVC) (Fowles et al., 2000; Power et al., 2004; Behm et al., 2004, Kubo et al., 2001). However, several studies (Fowles et al., 2000; Power et al., 2004; Kubo et al., 2001) used prolonged (15-60 min) stretching routines of single muscle groups, which do not reflect the stretching protocol routinely used in training. It appears that the duration of stretching may be a significant methodological reason for the diverse results in the previous studies indicating that the longer stretch incrementally reducing performance. Apart from the MVC, additional isometric force-time curve characteristics (IFTC), such as the index of rate of force development (IRFD), the index of relative force (IRF), and the maximum force achieved during the first 100ms (F_{100}) are important performance indicators of the neuromuscular system in producing force and are related to athletic performance (Katartzi et al., 2005). The present study investigated the effect of moderate static stretching of the lower limbs on MVC, IFTC of leg extensor muscles, and EMG activity of the rectus femoris (EMGRF), biceps femoris (EMGBF), and gastrocnemius (EMGGS) muscles.

METHODS:

Participants: Ten male volunteers (age 19.7 $\pm$ 1.4 years; height 177 $\pm$ 4.8 cm; mass 72.6 $\pm$ 8.4 kg) were recruited as subjects from the university population (physical education students). All participants completed two different warming up programs performed on two different days. During the first day of testing they performed a warm up consisting only of jogging for 10 minutes. After one week, they performed a warm up which included 10 minutes of jogging followed by seven static stretching exercises for the major muscle groups of the lower limbs. Following the warm up, subjects were tested as described below. All procedures were carried out in the laboratory of Sports Biomechanics, Department of Physical Education, Serres, Greece.

Stretching Protocol: The static stretching protocol consisted of following seven static stretching activities designed to stretch all the major muscles groups of the lower limbs: sit and reach stretch, lotus stretch, heel cord stretch, standing half lotus stretch, prone buttocks kick, standing quadriceps strength, and half kneeling quadriceps stretch (Kokkonen et al., 1998). Each participant performed all seven stretching exercises, three repetitions per exercise for each leg. Each stretching exercise was held after onset of pain for 30 sec followed by a 20 sec relaxation.

Instrumentation: A uniaxial load cell (AMD Co. Ltd., LC 4204-K600) with an aluminum rubber plate positioned vertically to the ground (combined error 1% and sampling frequency 1000 Hz) was used for maximal isometric force measurement. A specially designed leg press apparatus was used for the measurement. The device consisted of a metal frame, a chair, and the load cell fixed under a metal bar. A Velcro strap was placed around the waist to stabilize the body. The load cell was connected to a PC equipped with an A/D (analog/digital) card, a math processor, and specially designed software for data collection and analysis.

The EMG activity was recorded using the EMG interface module of the Ariel Performance Analysis System (APAS) (Ariel Dynamics Inc.) sampling at 1000 Hz, a common mode rejection ratio greater than 100db at 50/60 Hz, a measurement bandwidth ranging from 8 to 500 Hz and a gain of 400. Bipolar surface EMG electrodes (inter-electrode distance=1 cm) with a pre-amplifier were placed on the skin, above the belly of the rectus femoris, biceps femoris, and gastrocnemius muscles.

Testing Procedures: Maximal isometric force of the bilateral leg extensor muscles (hip, knee, and ankle extensors) was measured in a sitting position with the knee angle at 120^{o}. Participants placed their feet on the metal bar to which the load cell was fixed and performed a MVC. Participants were instructed to exert their maximum bilateral leg extensor force as fast and hard as possible and hold it for a maximum period of 3 seconds. Each participant completed two trials separated by a three minute interval. The trial recording the highest force was analyzed. Reliability indexes ranged from .95 to .98 for the isometric strength. From the force-time curve, maximal isometric force (MVC) and two explosive force measures were determined. The first, explosive force (F_{100}) was defined as the peak force exerted during the first 100ms of the contraction. The second, index of rate of force development (IRFD), was defined as the percentage ratio of peak force achieved during the first 100ms of F_{maxiso} to maximal isometric force [IFDR=(F_{100}/ F_{maxiso}) x 100] (Katartzi et al., 2005). In addition, an index of relative force (IRF), defined as the ratio of F_{maxiso}/Body weight, was calculated (Katartzi et al., 2005).

EMG activity of the rectus femoris, biceps femoris, and gastrocnemius was collected during the MVC. The raw signal was amplified, full wave rectified, and integrated over the duration of the maximal voluntary contractions. Integrated EMG in each MVC was divided by the integration time to derive average integrated EMG (AEMG).

Statistical analysis: Statistical analysis was performed on SPSS for Windows (version 10.0). Descriptive data included means $\pm$ SD. Dependent variables in the present study were AEMG (3 muscles), MVC, F_{100}, IRF, IFDR, and time to MVC (T_{MVC}). Paired t-tests were used to examine if there were any differences between the two warm-up conditions on each dependent variable.

RESULTS: Table 1 presents the results of the study. As it is shown, no significant differences were observed between jogging and jogging/stretching in MVC (1% decrease), F_{100} (7.8% decrease), IRF (1% decrease), IFDR (3.5% decrease), T_{MVC} (4.8% decrease), AEMGBF (14.3% increase), and AEMGGS (1.6% decrease). Jogging/stretching resulted in significant reduction (0.33 $\pm$ 0.16 mV vs. 0.26 $\pm$ 0.13 mV; $p < .01$) in the AEMGRF.

Table 1. Effect of Stretching on Performance Variables (Mean ± SD)

Variable	**Jogging**	**Jogging/stretch**
MVC (N)	3291.9 ± 881.3	3265.7 ± 900.6 ^{NS}
F_{100} (N)	1398.8 ± 439.8	1290.1 ± 416.9 ^{NS}
IRF (index)	4.641 ± 1.155	4.601 ± 1.201 ^{NS}
T_{MVC} (msec)	905.8 ± 275,72	871.5 ± 310.7 ^{NS}
IRFD (%)	42.034 ± 11.55	40.54 ± 10.42 ^{NS}
AEMGBF (mV)	0.14 ± 0.08	0.16 ± 0.09 ^{NS}
AEMGGS (mV)	0.61 ± 0.32	0.60 ± 0.33 ^{NS}
AEMGRF (mV)	0.33 ± 0.16	0.26 ± 0.13 *

^{NS} no significant differences
$^{*}p$ <.01

DISCUSSION: The influence of stretching on maximal voluntary contraction and isometric force-time curve characteristics has important implications in sport performance and rehabilitation. The results of the present study indicated that a moderate volume of static stretching of the lower limbs altered neither the MVC nor the isometric force-time curve characteristics. Of the 3 muscles tested, only one's EMG activity (AEMGRF) was significantly reduced (Table 1).

Although there was a slight decrement of the MVC, this decrement was not statistically significant. Previous studies have reported conflicting results, with decrements, or no changes in MVC after various stretching protocols (Fowles et al., 2000; Power et al., 2004; Kubo et al., 2001). The lack of a significant loss of MVC may be attributed to choice of muscles stretched and the type and/or the duration of stretching programs (Fowles et al., 2000; Power et al., 2004; Kubo et al., 2001; Behm et al., 2004). In the present study, the non significant changes of MVC may be attributed to the type (static and non-assisted stretching), intensity (onset of pain), and/or duration of stretching.

Although previous investigators have examined the effect of stretching on MVC, maximal peak torque, explosive strength, and the rate of force development (Fowles et al., 2000; Nelson & Kokkonen, 2001; Kokkonen et al., 1998), there is no information regarding the effect of stretching on the isometric force-time curve characteristics. These characteristics include the F_{100}, IRF, IRFD, and T_{MVC} and represent the ability of the neuromuscular system to develop maximal force rapidly. The findings of the present study indicated that a static stretching protocol produces slight decrements, but non-significant changes. It seems that the volume and/or the duration of the stretching protocol used in the present study might not be sufficient to decrease significantly the F_{100}, IRF, IRFD, and T_{MVC}.

According to previous investigators (Cornwell et al., 2002), the inducement of the EMG activity of the stretched muscles may be due to the response of Golgi tendon organs and low threshold pain receptors. The AEMGRF was reduced significantly after the static stretching protocol by 21%, whereas no significant changes were found in AEMGBF and AEMGGS. It should be noted, however, that the only muscle group that was stretched in more than one exercise (three stretching exercises) was the quadriceps (270 seconds of total stretching). It is possible that the Golgi tendon organs and pain receptors (partially) responsible for inhibiting the neural pathways and muscle activation (Moore, 1984) may require prolonged stimulation to be effective inhibitors of EMG activity. Hence the AEMGRF decrement might have been due to the larger volume and/or the duration of stretching exercises in comparison to biceps femoris and gastrocnemius, which were stretched for less time. However, the net result of the effect of the stretching protocol in this study, although induced a decrease in AEMGRF, was not sufficient to significantly influence the MVC and the other force – time parameters.

CONCLUSION: In conclusion, a moderate volume and duration of static stretching of the lower limbs resulted in non-significant decrements in MVC and isometric force-time curve characteristics. Net neural inhibition, as it is reflected in AEMG activity of the rectus femoris, biceps femoris, and gastrocnemius muscles, did not alter the above parameters.

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