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# ADAPTATIONS OF MUSCLE-TENDON UNIT TO A 8-WEEK STATIC STRETCHING PROGRAM OF TRICEPS SURAE MUSCLES

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## SUMMARY
This study aimed to use ultrasound imaging and dynamometer measurements to track the chronic adaptations of peak passive torque (PPT), maximum range of motion (ROM) and myotendinous junction (MTJ) displacement of medial gastrocnemius (MG) muscle of 14 men submitted to a static stretching training. Participants were assigned either to a group that underwent static stretching of the triceps surae muscles 4-5 times a week during 8 weeks (SG) or to a control group (CG). PPT, maximum ROM and MTJ displacement presented a significant increase after training (25, 26 and 35%, respectively) for SG with no significant differences for CG. The results suggest that an 8-week static stretching program is able to promote changes in the overall flexibility of the muscle-tendon unit.

## INTRODUCTION
Stretching is commonly applied to enhance performance in sports and reduce or prevent the risk of injury [1,2]. Several studies have investigated the acute and chronic effects of stretching in maximum range of motion (ROM)[1,3]. Despite of the significant impact in ROM, there are controversial results concerning the changes at the muscle structural level or at neural components response, such as increased stretch tolerance, that could explain this gain. Some mechanical theories, such as viscoelastic deformation, plastic deformation, increased number of sarcomeres in series and neuromuscular relaxation are reported [4], suggesting mechanisms that can generate these changes.

Data related to muscle and tendon stiffness, such as peak torque and myotendinous junction (MTJ) movement during passive joint mobilization are not conclusive. Results of decreased muscle-tendon unit (MTU) stiffness and changed MTU viscosity and elasticity [3,5] are counteracted to others reporting that changes in ROM were not accompanied by changes in MTU stiffness, after 3- and 8-week stretching training programs [2,6,7]. This study aims to assess changes in MTJ behavior, PPT and maximum ROM after an 8-week static stretching program.

## METHODS
The study included 14 men(18.5±0.52 years) with no history of musculoskeletal injuries. All volunteers signed the consent form and the study was approved by the Institution's Ethics Committee (031-2007). Participants were randomly assigned to one of two groups: one submitted to an 8-week stretching program of triceps surae muscles (SG, n=8) and one control group (CG, n=6). The stretching protocol, performed 4-5 times a week during 8 weeks, consisted of 2 sets of 30 seconds of 2 static exercises with an interval of equal duration. In the first exercise, the participants stood on a raised platform on the balls of their foot, then dropping the heel down toward the floor while maintaining the knee joint fully extended. In the second, the subjects leaned forward trying to reach the floor with the hands while the right leg was positioned back with the heel firmly positioned on the floor and the left leg ahead with the knee flexed.

During the evaluation tests, the subjects were positioned at the dynamometer (Biodex System 4 Pro - Biodex Medical Systems Inc, New York, USA) with the right knee in full extension and the right foot attached to the dynamometer footplate. ROM was then determined by passive mobilization at a velocity of 5°/s from 120° of plantar flexion up to the limit of dorsiflexion until each individual reported discomfort that was registered as the maximum ROM. Thereafter, a 4-cm ultrasound probe (T2000- Terason Ultrasound, Teratech Corporation, Burlington, USA), with frequency bandwidth of 6-11MHz, was fixed to the skin in the middle axis of the muscle over MTJ to initiate the test. The test consisted of 3 consecutive ankle passive mobilizations in the amplitude previously determined for each subject. Participants were instructed to avoid resistance and myoelectric silence was verified with electrodes (Ag-AgCl, Meditrace, Kendall, USA) positioned on lateral gastrocnemius muscle (EMG System, Brazil, 106 dB CMRR), whose output signals passed through a analog-to-digital converter operating with a sample frequency of 1kHz. During the mobilization, ultrasound videos of the MTJ displacement of MG, synchronized with the EMG and torque signals, were recorded. PPT was extracted from dynamometer data. MTJ displacement during passive mobilization was measured with image analysis software (ImageJ - National Institute of Health, Maryland, USA) in ultrasound videos. The structure displacement (straight distance between the image lateral border and MTJ) was quantified at intervals of 0.5s in a pre-selected frame range of 90° to the maximum ROM (Figure 1). Paired t-tests compared PPT, maximum ROM and MTJ displacement before and after training ($p<0.05$).

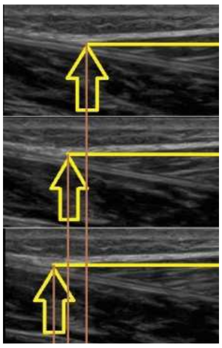

**Figure 1**: MTJ displacement during ankle dorsiflexion. The displacement of the yellow line tips (arrows) correspond to the total MTJ displacement.

## RESULTS AND DISCUSSION

Values of PPT, maximum ROM and MTJ displacement before and after training of SG are presented in Table 1. No significant difference was found in the CG.

**Table 1:** Mean, standard deviation and p-value of peak torque, maximum ROM and MTJ displacement of SG before and after training

| | Pre-test | Post-test | p-value |
|---|---|---|---|
| **Peak Torque (N.m)** | 31.16±4.88 | 39.28±7.72 | 0.026 |
| **Maximum ROM (°)** | 24.44±7.35 | 30.55±5.87 | 0.020 |
| **MTJ displacement (cm)** | 0.97±0.46 | 1.31±0.40 | 0.038 |

The 25% increase in ROM demonstrated that the 8-week static stretching program was effective in altering the maximum range of motion, which is consistent with previous studies [1,3]. This increase in ROM was accompanied by a 26% increase in peak passive torque, and this can be justified since the participants achieved a proportional higher maximum dorsiflexion angle at which the value of peak torque was determined. Similar results were presented in a study of acute effects of static stretching done by Mizuno et al. [8], who demonstrated that passive torque at end ROM was significantly increased (from 11 to 15%) after stretching. Further analysis may indicate if the passive torque at a specific angle achieved before and after training was lower for the stretching group, as in the study of Nakamura et al. [9], who demonstrated a reduction in the passive torque at 30° of dorsiflexion after a 4-week static stretching training of GM.

MTJ displacement was 35% higher after the training, which is corroborated by previous studies, such as the one of Morse et al. [10], that investigated the immediate effects of 5-min of stretching sessions on the flexibility of overall MTU and also on muscle and tendon stiffness. The authors reported MTJ displacement (between 0 and 25°) increase from 0.92±0.06 to 1.16±0.05cm (approximately 26%), suggesting that such increase accounted for all the additional MTU elongation after stretching since they indicated that no change in tendon properties occured. These results were complemented by a study of Nakamura et al. [11], which applied a 5min static stretching stimulus and observed an increase of MTJ displacement from 1.08 to 1.48cm immediately after and of 1.20 cm 10 minutes after the stretching. Both studies explain that changes in properties of the intramuscular connective tissue (endomysium, perimysium and epimysium), instead of lengthening of the muscle fiber, may contribute to muscle stiffness reduction related do increased MTJ displacement due to flexibility training. Our results are corroborated by a study of chronic effects of stretching training that also suggested a decrease of stiffness of the GM after the 4-week static stretching training program since MTJ displacement increased significantly in the stretching group, whereas no significant change was noted in the control group [9]. The authors suggest that the applied training program was effective in decreasing MTU stiffness, in particular muscle stiffness.

## CONCLUSIONS

Our results show an increase in all the parameters (PPT, maximum ROM and MTJ displacement), suggesting an overall increase in muscle flexibility after an 8-week static stretching program and a possible decrease in muscle stiffness due to altered material properties.


## ACKNOWLEDGEMENTS

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