THE CHRONIC EFFECT OF STRENGTH AND FLEXIBILITY TRAINING ON STIFFNESS AND RANGE OF MOTION

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Twelve male subjects were in the training group (T) who performed concentric strength training (CON) on one side and concentric plus flexibility training (CON_F) on the other side; other 10 subjects served as a control (C). A strength and stretch tests were administered before and after the training period. After 6 weeks of training a significant difference between pre and posttest was found for the 1 repetition maximum (1RM) test on T group. The ROM increased significantly only in CONC_F group. No differences between groups or time existed was found for stiffness. Concentric training was able to enhance strength without any alterations in the stiffness of muscle-tendon unit (MTU). The concentric training combined with flexibility training was able to increase strength and ROM without any augmentation in stiffness.

KEY WORDS: stretching, strength, stiffness, range of motion.

INTRODUCTION:

Strength training is able to promote neural and morphologic adaptations in the muscle-tendon unit (MTU). One of the adaptations associated with the concentric training is the increase in muscle cross-sectional area (Klinge et al., 1997). According to Chleboun et al. (1997), the muscular volume could explain 84% of the stiffness in MTU. Stiffer muscles are more susceptible to damage after eccentric exercise (McHugh et al., 1999). This could be an evidence of a positive association between flexibility and muscle injury.

The effects of flexibility training are associated with alterations in the viscoelastic properties (Kubo, Kanehisa & Fukunaga, 2002; Taylor et al., 1990) and stretch tolerance with no significant change in tissue properties (Magnusson et al., 1996). If the strength training could be able to increase muscle stiffness and reduce range of motion (ROM) and the flexibility training could increase ROM and decrease stiffness so the flexibility training combined with concentric strength training could minimize the alterations in stiffness and still have positive results in the strength and ROM. The purpose of the present study was to investigate the long-term effect of strength training alone and strength combined with flexibility training on stiffness and ROM during knee extension.

METHOD:

Data Collection: Twenty-two male, physical education students of UFMG, volunteered to the study. They were matched for maximum ROM and passive torque peak and distributed in two groups: control (C) (n=10) and training (T) (n=12).

Subjects were free of any lower extremity, back or pelvis pathologies for the last 6 months, had not participated in any strength or flexibility training program within the last 3 months and showed a minimum of 20º ROM restriction for knee extension in the *Flexmachine* (BIOLAB, UFMG, Brazil).

All participants volunteered, after giving informed consent for this study, which was approved by the local Ethic and Research Committee. The mean values (±SD) for the age, height and body mass were 24.2 yr (±5.2), 177.3 m (±6.8) and 75.1 kg (±6.3) for control group and 22.1 yr (±1.4), 175.9 m (±5.6) and 70.3 kg (±12.0) for training group, respectively.

The study design had one session of familiarization and after a minimum interval of 48 hours, a pretest for flexibility (ROM and stiffness) and dynamic concentric strength (one repetition maximum – 1RM) was performed. Thereafter the concentric training and flexibility training took place for 6 weeks period, which preceded the posttest for flexibility and strength. The sequence of evaluation of lower limbs in the pretest was maintained for the posttest. The volunteers were instructed not to participate in another strength or flexibility training during the study. The *Flexmachine* was used to measure and training flexibility (figure 01). The 1RM and strength training used the seated leg curl machine (Master Equipments, Brazil) (figure 02).

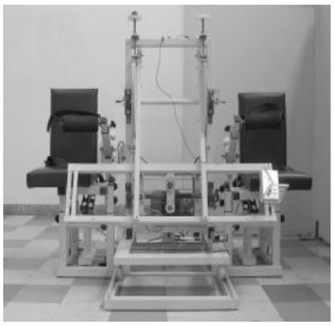

Figure 1: Flexmachine

Figure 2: Seated leg curl machine

The training group performed concentric training bilaterally, while only the right lower limb performed flexibility training. For this reason the training group was divided into concentric training (CON) and concentric and flexibility training (CON_F). Measurements were gravity corrected for the weight of the leg and foot.

Flexibility: The flexibility tests (pre and posttest) consisted in 3 repetitions for each lower limb. In each trial the knee was passively extend in a constant velocity of 5º/s until the maximum ROM determined by each individual, and immediately returned to the initial position. The electromyogram of the hamstring muscles was used to control for electrical activity during flexibility tests. All *Flexmachine* adjustments were registered to be used in the posttest. Similar flexibility testing procedure had been used in other studies (Klinge et al. 1997; Chagas & Schmidtbleicher, 2001).

Stiffness is defined as the ratio of passive torque and ROM, graphically represented by the passive torque x ROM curve slope. Pre and posttest passive torque x ROM curves were analyzed simultaneously, and the cut off point of the posttest curve was determined by the pretest maximum ROM, allowing the stiffness to be compared to the same delta angle. Thereafter the curves were divided in 3 parts and the central third was used to calculate the stiffness (Magnusson et al., 1996).

The flexibility training was performed 4 minutes after the concentric training (Fowles, Sale & MacDougall, 2000) with a frequency of twice a week (Klinge et al., 1997), during a 6 weeks period. The flexibility training consisted of 4 sets (Taylor et al., 1990) of 20s passive static stretching.

Strength: Before 1RM the subjects were requested to perform one set with submaximal weight. The 1RM test consisted of a maximum of 6 trials performed bilaterally with a 3-5 minutes rest period between efforts. The volunteers had to complete the whole range of motion, from 0º (full extension) to 90º of knee flexion independently of the time of execution. The concentric training consisted of 3 sets of 10-12 repetitions at 70% of 1RM, for 6 weeks. The rest period between sets was 120s. Each repetition had to be done in full ROM from 0º (full extension) to 90º of knee flexion during 3s. The 70% 1RM was individually adjusted to match the progressive increase in muscle strength and to respect the established training load. Another 1RM test was carried out after 3 weeks of training to control the training intensity.

Data Analysis: The reliability of the procedures of the study was verified with the intraclass correlation coefficient (ICC 3.1) and the method error (ME) (Sale, 1991). For this procedure both legs of the control group were used.

The 1RM performance was analyzed for training and control group using the paired T-test to assess whether any differences existed between pre and posttest. Repeated-measures analysis of variance (RMANOVA) was used to assess time effects and to determine if difference scores varied among groups. Variations in mean difference scores were compared using the *Scheffé* post hoc analysis. An alpha level of p<0.05 was considered significant. The statistical procedures used the sotfware Statistica 5.0.

RESULTS:

The maximum ROM showed a ICC of 0.94 and ME of 6.8% and the stiffness showed a ICC of 0.86 and ME of 20.1%.
A significant difference between pre and posttest was found for the 1RM performance on the T group (p<0.001). There was no significant difference between groups in the pretest. The statistical power was 1.00 for 1RM, 0.99 for ROM and 0.22 for stiffness.
Before the training period, there were no differences between groups for the initial measures of the maximum ROM or stiffness. Maximum ROM increased significantly in CONC_F group (p<0.001), with no change for groups CON (p=0.93) or control (p>0.99) (figure 03).
RMANOVA indicated no significant differences between groups (F= 0.1879; p=0.830) or time (F=1.468; p=0.235) for stiffness (figure 04).

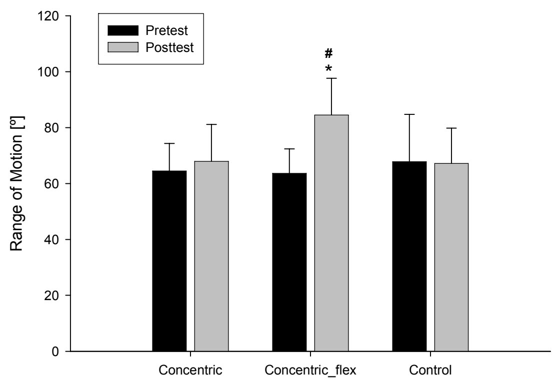

Figure 3: Mean ROM in CON, CON_F and C groups for pre and posttest.
* p<0.001 Difference between pretest and posttest
# p<0.05 Posttest difference for CON and C

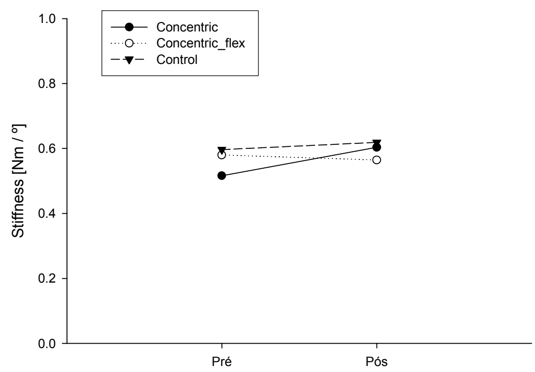

Figure 4: Mean Stiffness in CON, CON_F and C groups for pre and posttest.

DISCUSSION:

The concentric training adopted in the study was able to increase the strength in the T group corroborating with other researches (Klinge et al., 1997, Hortobagyi et al., 1996). But there was no change in the stiffness of MTU for either training group.
The strength training is able to promote neural and morphologic adaptations. During the initial weeks of training the strength augmentation is associated with neural adaptations. After a period of strength training the contribution of morphologic adaptations like hypertrophy increases (Moritani & DeVries, 1979). Our study did not measure the hypertrophy in hamstring muscle group, but the increase in cross-sectional area of muscle could be responsible for a stiffer MTU (Chleboun et al., 1997). The stiffness in MTU in the present study did not significantly change from pre to posttest. It is possible that the morphologic adaptations that took place after the training period were not enough to change the stiffness of MTU. The increase in strength here also could be a result predominantly in the neural adaptations.
The results of this study corroborates with other researchers for the flexibility training (Bandy, Iron & Briggler, 1997, Magnusson et al., 1996). The maximum ROM increased significantly between pre and posttest for the CON_F group only. This was expected because the training

was designed with loads adopted in other study that showed long-term improvements (increase in ROM) (Bandy, Iron & Briggler, 1997). This increase in ROM could be a result of an increase in stretch tolerance. Magnusson et al. (1996) showed that the increase in ROM for hamstring muscle group after a long-term passive stretching regimen was a consequence of the increased stretch tolerance rather than a change in viscoelastic properties of the muscle. These authors justified this conclusion based on the associated increase of passive torque peak. However the viscoelastic properties not seem to occur in the present study, since after the 6 weeks flexibility program no significant change was shown in stiffness. According to Taylor et al. (1990), the change in viscoelastic properties of MTU would allow it to reach a higher deformation value for the same stress previously applied. This change in viscoelastic properties would also be noticeable at the passive torque-ROM curve and consequently at stiffness.

CONCLUSION:

The results of the present study show that 6 weeks of isolated concentric strength training does not influence the flexibility parameters, ROM and stiffness. The flexibility training when associated with the strength training of knee flexor muscles improves ROM and strength of knee flexor muscles, with no influence on muscle stiffness.

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