

COMPARATIVE STUDY OF DIFFERENT STRETCHING PROTOCOLS ON FLEXIBILITY AND PASSIVE RESISTANCE OF HAMSTRINGS

Suk Ping Chan and Youlian Hong
The Chinese University of Hong Kong, Hong Kong

This investigation determined the effects of different static stretching protocols on flexibility and passive resistance of the hamstrings. Forty healthy young adults were randomly assigned into one of four groups. The two training groups underwent static stretch training by a four-week and an eight-week protocol, respectively. The other two were control groups. A significant increase in hamstring flexibility was found in both of the two training groups. No difference was found in the amount of range of motion (ROM) gained between the two training groups. An increase in passive resistance was only found in the four-week training group. Both protocols are effective in terms of improving hamstring flexibility. However, if injury is reduced when there is relatively lower passive resistance at end-of-range then the eight week regimen would be recommended.

KEY WORDS: flexibility, range of motion, static stretch protocol, passive resistance, hamstrings.

INTRODUCTION: Static stretching of muscles has been incorporated into warm up and cool down exercises, training programs, and rehabilitation programs. A protocol for static stretching has only partially been clarified by a few recent studies, with conflict still surrounding what constitutes an optimal protocol.

The stretching duration suggested varies from 10 s (Borms et al., 1987), to 15 s (Madding et al., 1987), to 30 s (Bandy and Irion, 1994). The number of stretches suggested by Taylor et al. (1990) was four, but this was based on research involving an animal muscle tendon. Furthermore, the design of these studies was limited by only a single bout of stretching, or lack of specification of training intensity, or lack of proper fixation of the body during measurement of the ROM. The scientific foundation to support the use of an objective protocol was still lacking. The purpose of this study is to provide further information to assist in designing flexibility training protocols.

METHODS: Subjects: Forty healthy volunteer (24 males and 16 females, 20 ± 3 years of age, 167 ± 8 cm of body height, 58 ± 9 kg of body weight) recruited from University students in Hong Kong served as subjects. The subjects had no history of any cardiac problem or metabolic disease, knee, hip, or spinal conditions that necessitated medical intervention. Subjects had signed an informed consent form approved by the Clinical Research Ethics Committee of the Chinese University of Hong Kong.

The subjects' dominant leg was used in all testing and was defined asking the subject to kick a football towards a wall continuously for five times. The more frequent leg used for kicking the ball was identified as the dominant leg.

Protocol: Subjects were randomly assigned to one of four groups. The subjects in the Group 1 underwent static stretching of the hamstrings of the dominant leg. A stretch lasted for 30 seconds to a point of 'maximum stretch without pain'. Each set consisted of five repetitions of the single stretch with a rest interval of 30 seconds in between and for 1 set only; three times a week and for eight weeks. While for the subjects in the Group 2 performed two sets of the same hamstring stretches, each time with 1-minute rest in between; three times a week and for four weeks. Group 3 and 4 acted as controls for Group 1 and 2 respectively, with both groups receiving no stretching treatment.

Stretch Treatment: Before each stretching treatment, subjects in the training groups were asked to warm up for 5 minutes with local jogging. The stretching procedure started with a sitting position. Subjects extended the knee of the dominant leg and folded the other leg to

the side and kept the back straight while bending **forward** at the hip slowly and gently until feeling 'maximum stretch without pain' of the hamstrings. Subjects were monitored during each stretching session to ensure proper performance of the stretching methods.

Assessment: Before each pre- and post-test, each subject undertook warm up exercises for 10 minutes on a treadmill with a speed of 1.7 mile per hour with 10 percent grade. Each subject was then put on the custom designed couch with a starting supine position (Figure 1). The dominant hip joint was flexed and rested on a specially designed platform with the contralateral limb (the non-dominant limb) partially flexed at the hip and knee to assist in stabilising the pelvis by placing a roll of towel underneath the knee. The pelvis and both thighs were fixed by straps. The ankle of the testing limb was kept in **neutral** position by **Coban** and tape. A Penny and Giles Goniometer (Penny and Giles Biometrics Limited, United Kingdom) was aligned on the lateral aspect of knee to measure the knee ROM.

For the passive knee extension test, the Cybex Norm dynamometer (Cybex International, USA) was used to extend the knee at the angular velocity of one degree per second using continuous passive mobilisation (CPM) mode, and to measure the passive resistance given by the hamstrings in terms of Newton-metres (Nm). The lower border of the calf pad was placed approximately two finger widths proximal to the medial malleolus. The Cybex Dynamometer rotated in an arc whose centre coincided with the axis of knee joint rotation.

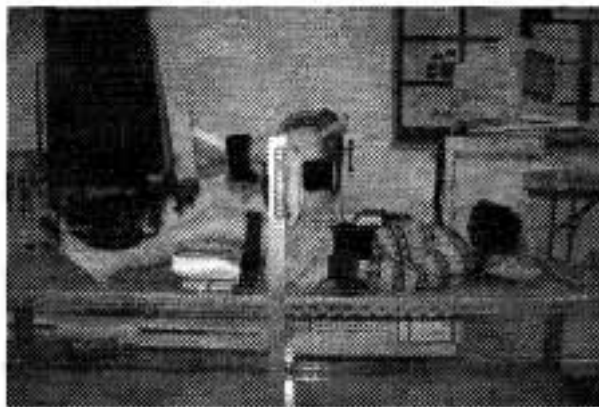


Figure 1 - Passive knee extension test

The subjects were instructed to say 'stop' when they reached the end point of 'maximum stretch without pain' at the hamstrings of the dominant leg. The passive resistance produced by hamstrings in terms of a reaction torque was measured by the dynamometer when the 'stop' point was reached. At the same time, the ROM of the knee was also recorded. The measurement was repeated for two times, and the mean of the two readings was used for the data analyses.

Data Analysis: The SPSS package was used to perform a two-tailed dependent t-test to determine if there was any difference between pre and post-test with regard to ROM of **knee** and passive resistance. To determine whether the training effects among the four treatment groups were different, a one-way ANOVA and a follow-up testing Scheffe test were used to test the significance of mean changes between groups. All gain scores, which obtained by subtracting the post-test values from the pre-test values, were used for ANOVA analysis. All probability levels were set at $p \leq 0.05$.

RESULTS: Comparison Between Pre- and Post-test: Significant differences ($p \leq 0.05$) in ROM were found between pre and post-test in both training groups. The ROM of knee increased significantly by 11.2 degrees and 8.9 degrees after eight and four weeks of training, respectively. No significant changes were shown in the ROM of the knee for the control groups.

An increase of passive resistance of hamstrings was only found in the Group 2 (four-week protocol) after training. The passive resistance was increased by 4.7 Nm.

Comparison Between Trained and Untrained Groups: Statistical significance, $F(3, 36) = 22.34$, $p \leq 0.05$, was observed for mean differences of the ROM among the four groups. The follow-up Scheffe test showed that both training groups had statistically greater gains in ROM than the control groups. However, no significant difference was found in ROM gained between the two training groups.

For the torque data, the changes in passive resistance for Group 1, 2, 3, and 4 were -1 Nm, 4.7 Nm, 0.1 Nm and 0.4 Nm, respectively. However, the values among the four groups were not significant.

DISCUSSION:

Hamstrings Flexibility: Both training groups had significant ROM improvement, indicating that flexibility of hamstrings can be improved effectively using static stretch training by the eight-week protocol and the four-week protocol developed in this study. When comparing the amount of changes in ROM between the two training groups, no significant difference was found. If the effectiveness of static stretching is taken from the gain in range alone, it makes little difference between the four-week and the eight-week protocol. The need for using a longer duration of stretching, therefore, may be questioned.

The improved ROM showed by both stretching groups in the present study may be indicative of the viscoelastic properties (Magnusson et al., 1995; Taylor et al., 1990) and lengthening changes (Tardieu et al., 1982; Williams and Goldspink, 1978) in the hamstrings. By using an *vivo* animal stretch model, Taylor et al. (1990) demonstrated sustained musculotendinous unit elongation due to stress relaxation and creep in simulated static stretching and cyclic stretching, respectively. Animal muscle immobilized in lengthened positions demonstrated an increased number of sarcomeres (Tabary and Tardieu, 1972; Williams and Goldspink, 1978) and a shift in the passive length-tension curve, indicating increased muscle extensibility.

Hamstrings Passive Resistance: Toft et al. (1989) revealed that passive tension increased exponentially with the change in muscle length. This increase is explained by a greater number of parallel tissue elements being consecutively loaded with the deformation. For a gentle stretch, only a few elements contribute to the stiffness, the rest being slack; for a larger amplitude of stretch, more elements contribute to the tension (Viidik, 1973). In microscopic study of rabbit Achilles tendons, Viidik (1972) demonstrated a parallel wavy structure of the collagen fibrils in the unstretched tendon. During passive elongation of the tendon, the waviness disappeared gradually and simultaneously with an exponential increase of passive tension. Therefore, if the range is further, the passive resistance should increase. In the present study, both training groups show increases in ROM after training. This increase in ROM should be accompanied by an increase of passive resistance. However, the passive resistance of Group 1 remained unchanged at the end point, and presumably concomitant increased in ROM. This may due to the fact that adaptation of muscle and connective tissue takes place. In contrast, in Group 2, the passive resistance increased at the end point. This may due to insufficient adaptation of soft tissue in four weeks duration. Apparently the passive tension changes are related to the duration of the stretching program last.

Muscle is a very adaptable tissue. Williams and Goldspink (1973) demonstrated that immobilization of the *soleus* muscles of adult mice in the lengthen position continuously for a few weeks duration resulted in an increase in sarcomere for a few weeks duration. It implies that time is necessary for adaptation to take place. Furthermore, Tardieu et al. (1982) demonstrated length adaptation of connective tissue did not increase significantly in adult cat *soleus* muscles in a lengthened position even for 28 days immobilisation. This further suggested adaptation of either muscle or connective tissue takes a certain time.

'Tight' hamstrings are associated with various problems, including specific disorders of the back (Cailliet, 1982) and musculoskeletal injuries (Ekstrand and Gillquist, 1982). After stretching, the muscles and tendons are easier to extend and, therefore, are less likely to be overstretched by an external load thus diminishing the risk of injury. If safety was taken into consideration, possibly the eight-week protocol produces less resistance and is therefore safer than training with the four-week protocol. Since the passive resistance in the Group 2 is significantly increased at the end point, the eight weeks training period is recommended in terms of reducing risk of injury.

CONCLUSION: Both training protocols are effective in terms of improving hamstrings flexibility. Alternatively, it is recommended to use the eight-week regimen in terms of reducing the risk of injury by incorporating a relatively lower passive resistance.

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