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INFLUENCE OF LOCAL COOLING AND WARMING ON THE FLEXIBILITY OF THE HAMSTRING MUSCLES

Brasileiro JS, Faria AF & Queiroz LL

Department of Physical Therapy, Federal University of Rio Grande do Norte, Natal, RN - Brazil

Correspondence to: Jamilson Simões Brasileiro; Av. Ayrton Senna, 1100, bloco 09, apto 503, Nova Parnamirim, CEP 59080-100, Natal, RN – Brazil, e-mail: brasileiro@ufrnet.br

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ABSTRACT

Objective: The aim of this study was to analyze the acute and chronic effects of cooling and warming on hamstring muscle flexibility. Method: Forty volunteers were randomly included in one of four groups (n=10): 1) control group; 2) stretching group, using a sustain-and-relax technique on the hamstring muscles, for two consecutive weeks; 3) stretching group preceded by applying cryotherapy (25 minutes) to the posterior thigh region; 4) stretching group preceded by warming using shortwave diathermy (25 minutes). Muscle flexibility was assessed using a board coupled to a goniometric system specially prepared for evaluating the extensor angle of the knee. Results: The three experimental groups significantly increased their range of motion in relation to the control group. The mean daily gains (considered to be acute effects) showed significant differences in favor of the group subjected to cooling, in comparison with the other two (increases of 2.6 ± 0.9°, 4.3 ± 1.5° and 2.4 ± 0.7° for groups 2, 3 and 4, respectively, p= 0.008). With regard to chronic effects, there were no significant differences between the three experimental groups, but they all differed from the control group (increases of 1.5 ± 0.5°, 11.1 ± 6.1°, 14.4 ± 5.4° and 14.4 ± 6.2°, for groups 1, 2, 3 and 4, respectively). Conclusion: Stretching sessions applied daily significantly increased hamstring muscle flexibility. The acute effects were greatest in the group subjected to cooling, in comparison with the groups with stretching alone and stretching plus warming. The chronic effects were not influenced by warming or by cooling.

Key words: muscle flexibility, stretching, cryotherapy, warming, hamstrings.

INTRODUCTION

Muscle flexibility exercises are among the exercise types most commonly used in rehabilitation and sports practice. Their aims usually include reducing the risks of injuries, minimizing late-occurring muscle pain and improving general muscle performance[1]. Muscle flexibility, in turn, has been defined as the ability of a muscle to be stretched, thereby enabling a joint (or possibly more than one joint) to move through its range of motion (ROM). On the other hand, loss of muscle flexibility is revealed through reduced capacity of a muscle to be deformed, thus resulting in reduced ROM[2]. Particularly in the field of rehabilitation, flexibility of the hamstring muscles is important in postural balance, complete maintenance of the ROM of the knees and hips, injury prevention and optimization of musculoskeletal function[3].

Seeking techniques that improve the protocols used in such interventions is one of the major therapeutic aims today among physical therapists, sports physicians and physical education professionals. Studies have, for example, been aimed towards discussing the ideal number of daily and weekly sessions, duration of stretching and techniques applied and analyzing the participation of neural and viscoelastic components during the program[1-6].

The neural component has been proposed as the means through which stretching produces a reflex response mediated by the muscle spindle, thereby increasing the contractile resistance of the muscle, particularly at the extremes of movement. This increased resistance during clinical maneuvers would restrict the tissue flexibility and consequently the efficiency of the intervention. This reflex response has been demonstrated in a variety of studies, but its relative contribution towards increased muscle resistance remains unclear[7]. On the other hand, the viscoelastic component of the muscle has been indicated as a mechanical factor that limits the passive and active stretching of contractile and elastic tissues[8], thus changing the ROM and the torque generated.

In this way, the use of resources that would reduce the neural discharge might, theoretically, reduce the activation of the muscle reflex and also the pain, thus increasing the individual’s tolerance to stretching maneuvers. A variety of studies have proven the capacity of applications of ice with this aim: this causes a reduction in the nerve conduction speed and consequently gives rise to less feeling of pain and lower spindle activity[9-11].

However, the study by Knight[10] indicated that, in addition to these effects, cooling caused an increase in tissue stiffness and consequently reduced the tissue viscoelasticity. Such increases in stiffness would be an undesirable effect during stretching maneuvers, considering that this would limit the tissue flexibility and consequently reduce the efficiency of the technique. Thus, resources that elevated this viscoelasticity would increase the efficiency of the stretching maneuvers, considering that they would reduce the tissue resistance. This has already been demonstrated when muscles are warmed up[12,13]. On the other hand, we are not aware of the existence of any studies comparing the chronic effects from associations between stretching, warming up and cooling down.

In this light, the aim of the present study was to evaluate the influence of local muscle warming up and cooling down, prior to stretching maneuvers, on the flexibility of the hamstring muscles in healthy subjects. Such effects would relate to acute changes (lasting for seconds or minutes after sessions) or chronic changes (lasting for more than one day) to the muscle tissues[5].

METHODS

Subjects

Forty subjects (12 men and 28 women) took part in this experiment. They were all undergraduate students, with mean age 21.5 ± 3.1 years, height 1.67 ± 11.5 cm and weight 67.3 ± 5.0 kg. Care was taken to ensure equal distribution in each group, with regard to gender proportions. None of the subjects presented any musculoskeletal disease in their legs, nor were they using any medication. All the individuals were given information about the aims of the study and they all signed a free and informed consent statement before their admission to the experiment. The study had previously been approved by the local research ethics committee (Protocol 036/2005).

Procedure

Firstly, the extensor angle of each subject's dominant knee was evaluated. Shuback et al.[3] stated that the flexibility of the hamstrings was frequently evaluated by means of this maneuver, which they called the AKET (Active Knee Extension Test). To acquire this measurement, the subject was positioned in dorsal decubitus, with the hip kept at 90 degrees, on a specially constructed adjustable bench with a universal goniometer attached to its axis (Figure 1).

A chest belt, a pelvic belt and three other belts supporting the thigh ensured that the non-evaluated segments remained stable. This apparatus was constructed based on the studies by Goeken & Hof [14,15], who validated the method for measuring the variable proposed. Thus, the greater the ROM obtained during active extension of the individual's knee was, the greater the flexibility of the hamstring muscles was (Figure 2), considering that the ROM during this maneuver is usually limited by the flexibility of this musculature[4].

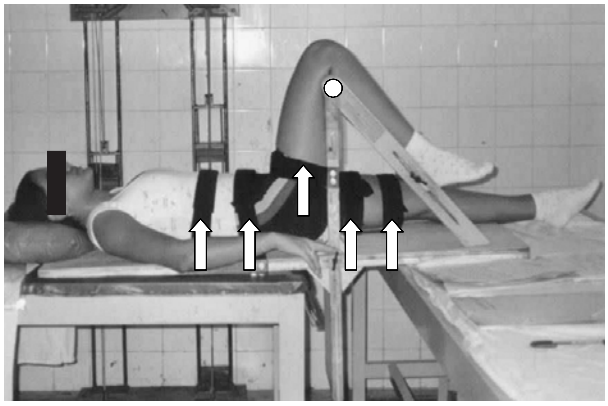

Figure 1. Overview of the instrumental setup: the mechanical axis of the goniometer was perpendicular to the sagittal plane and the knee extensor angle (circle) was recorded. Straps were fastened around the trunk, pelvis and thigh for stabilization (arrows).

Figure 2. The final position, with the leg lying on the board and the foot relaxed. The knee extensor angle was measured to evaluate the stretching of the hamstring muscle (modified from: Goeken LNH & Hof AL. Instrumental straight-leg rising: results in healthy subjects. Arch Phys Med Rehabil 1993; 74: 194-203).

Each measurement was repeated three times consecutively. In order to observe the reliability of the method, a pilot study was performed, involving 15 subjects. The initial and final angles, and also the gains achieved during the sessions, were measured three times for each subject. In this analysis, the inter-observer reliability indices were assessed by means of interclass correlation coefficients (ICC) and presented a value of 0.98.

Subjects who, during the initial evaluation attained values greater than 160° (taking 180° to represent complete extension) were excluded from the study.

Next, the individuals were allocated, by means of a draw, to one of the four groups evaluated:

a) Group 1 (n=10) was the control and only underwent the initial and final evaluations, which were carried out before and after the intervention period;

b) Group 2 (n=10) underwent the initial and final evaluations and also followed a protocol for stretching the hamstring muscles over a two-week period, totaling 10 sessions. For each maneuver, the volunteer was positioned in dorsal decubitus with the hips flexed and the knees kept at maximum extension, to the pain threshold. Next, the subjects were asked to actively extend the hips, while the investigators provided counter-resistance, thereby ensuring that the contraction was isometric (“contraction-relaxation” active stretching technique). Each contraction was maintained for 15 seconds, followed by 15 seconds of relaxation, and this was repeated four times. Each intervention thus lasted for two minutes and consisted of four cycles of 15 seconds of contraction followed by 15 seconds of relaxation. This protocol was put forward by Schuback et al.[3].

c) Group 3 (n=10) underwent the same protocol as Group 2 did, but the stretching maneuvers were preceded by applying ice compresses weighing 1.5 kg, in the form of packets on the posterior face of the thighs, for 25 minutes.

d) Group 4 (n=10) also underwent the same stretching procedures, but preceded by warming up provided by a shortwave device with plates (Siemens®, Germany), at an intensity of 25 mA in the posterior region of the thighs, using a coplanar layout for 25 minutes.

The measurements made before and after each session were used to evaluate the acute effects from the intervention, while the measurements made before the experiment and on the day after the end of the experiment were used to evaluate the chronic effects.

There was no warm-up exercise or stretching maneuver before the evaluations, with the aim of minimizing any possible effects on tissue temperature. All the evaluation procedures, the stretching procedures and the applications of cryotherapy and thermotherapy were always carried out by the same investigators. There was no sample loss of the course of the study, and the volunteers were instructed not to perform physical activities other those that the investigators asked for during the study.

Statistical analysis

All the statistical procedures were carried out by means of the GB-Stat School Pak® software. Before analyzing each group, the normality of the data distribution was checked by means of descriptive statistical procedures, using the Shapiro-Wilk test.

To analyze the acute effects, the knee extension angle was measured before and after each session, and the difference was recorded for all subjects, for each day of the intervention. To analyze the chronic effects, only the angle at the beginning and end of the study were registered for each of the subjects. The differences between these measurements were subjected to repeated-measurement Analysis of Variance (ANOVA), to compare between them. Whenever a cause of variation was significant, the Newman-Keuls *post-hoc* test was used in order to locate the differences between the groups. In all situations, the significance level used was $p \leq 0.05$.

RESULTS

Table 1 presents a summary of the results from the proposed treatments.

Evaluation of the acute effects showed that, for the three treated groups, there were significant increases in ROM in comparison with the values measured before each session. Thus, it can be assumed that the stretching maneuvers produced immediate gains in the extensor angle of the knee and hence the treatment increased the flexibility of the hamstring muscles. Moreover, there was a significant difference in the gain in ROM between group 3 (cryotherapy + stretching) and groups 2 and 4 (p= <0.01). Comparing groups 2 and 4, the critical level of significance was not reached.

Also in Table 1, the chronic effects in the three experimental groups and the control group can be seen. By the end of the treatment, the knees in the three experimental groups presented significantly increased ROM, in comparison with the control group, which confirmed the effectiveness

Table 1. Gains in knee extension in each group (means and standard deviations, in degrees), considering the acute and chronic effects, for Group 1 (control), Group 2 (stretching), Group 3 (stretching and cryotherapy) and Group 4 (stretching and shortwave diathermy).

	Acute effects (in degrees)	**Chronic effects (in degrees)**
GROUP 1	-	1.5 º (± 0.5)
GROUP 2	2.6 º (± 0.9)	11.1 º (± 6.1) **
GROUP 3	4.3 º (± 1.5) *	14.4 º (± 5.4) **
GROUP 4	2.4 º (± 0.7)	14.4 º (± 6.2) **
p	* Significantly different compared with Group 2 and Group 4 (p<0.01)	** Significantly different compared with Group 1 - Control (p<0.001).

of the maneuvers for increasing muscle flexibility. However, no significant differences were observed between the three treated groups with regard to increases in ROM of the knee. Therefore, it can be assumed that the three treated groups achieved increased muscle flexibility, independent of whether any warming up or cooling down resources were applied.

DISCUSSION

Acute effects

This study demonstrated that the three experimental groups achieved effective increases in hamstring muscle flexibility during the stretching sessions. However, there was a significant difference between the groups ($p< 0.01$), with greatest effectiveness in group 3, in which the stretching was preceded by cooling down with ice packs. Paradoxically, it has been suggested in the literature that cooling down has adverse effects on the viscoelastic properties of tissues. Knight[10] stated that "the stiffness of the conjunctive tissue increased and its extendibility decreased as the temperature went down", thus suggesting that "an association between cooling down and stretching is harmful when it is desired to increase the extendibility of the conjunctive tissue". Nonetheless, although these affirmations are admissible, cooling reduces the nerve conduction speed and therefore produces two other important effects during stretching maneuvers.

The first is a reduction in spindle discharge. The muscle spindle performs an important function during stretching of the musculature, considering that its facilitative stimulus increases the degree of tension in the agonist muscle, which limits muscle extendibility. Thus, the greater the sensory input is, the greater the motor discharge will be[3]. Once the spindle discharge has decreased, the interference from this stimulus, in relation to muscle tension, consequently reduces. This finding corroborates previous studies that demonstrated that muscle relaxation may be obtained through applying cryotherapy and suggested that the decrease in tension was the result from a reduced frequency of discharges from the muscle spindles[9,16].

The second effect from cooling down is a reduction in pain. It is often observed that the pain threshold during stretching maneuvers precedes the tissue limitation. Thus, the subjective feeling of discomfort in the posterior region of the thigh may reduce the efficiency of the maneuver, thereby minimizing the possible viscoelastic changes in the tissue[4]. Because the subject increases his tolerance to the maneuvers with cooling, greater stretching is enabled. Thus, the effects of the ice on the nerve conduction speed prevail over the changes in tissue extendibility.

No significant differences were found between group 2 (stretching alone) and group 4 (prior warm-up). Shortwave diathermy was chosen because this is a resource of proven efficacy in warming up deep tissue: muscle temperature increases of between 4 and 4.6° at a depth of 3 cm have been recorded using this resource[13,17]. Robertson et al.[13] also suggested that a temperature increase of 3 to 4°, maintained for at least five minutes, is sufficient for significantly increasing tissue extendibility. Although warm-ups preceding stretching maneuvers with the aim of increasing muscle extendibility would be the classical indication, the present study suggests that this is not the principal factor limiting the efficiency of these techniques: the intolerance to the maneuvers results primarily from a pain threshold that precedes the tissue limitation.

Chronic effects

These effects were evaluated on the day following the end of the intervention. All the three groups demonstrated significant increases in hamstring muscle extendibility, but without differences between them. This suggests that, independent of whether cooling down or warming up techniques are applied before stretching, chronic muscle changes depend solely on the efficiency of these maneuvers. Thus, the acute effects (for which cryotherapy is favored) are in fact temporary. On the other hand, the results obtained from the three experimental groups make it possible to validate the technique utilized (contraction-relaxation) for increasing muscle flexibility.

The implications from the present study fall especially on the clinical practice of physical therapy. Cooling is often indicated and warm-ups are particularly indicated before stretching maneuvers. These applications excessively increase the duration of the intervention and also the financial expenditure on the treatment and the complexity of the care. Since the immediate gains in which cooling down is favored are not reflected chronically in real gains in flexibility, it may be assumed that such interventions become unnecessary. Thus, the only determining factor for possible changes in the viscoelastic properties of muscles is the efficiency of the stretching maneuvers.

CONCLUSIONS

Within the experimental conditions proposed, the present study suggested that the acute effects from stretching were favored by application of cooling using ice packs before the maneuvers, while there was no difference between the groups receiving warming and stretching alone. The chronic effects were evident in all three experimental groups, in comparison with the control, but without any differences between the groups receiving cooling, warming and stretching alone. Thus, the data obtained do not provide support for the use of cooling or warming prior to stretching maneuvers, when it is desired to boost the chronic effects from these maneuvers. The finding from the present study are expected to be limited to subjects presenting integrity of the neuromotor system, and should not be extrapolated, for example, to individuals presenting neurological impairment. It is suggested that similar studies should be performed, especially to assess the effects of cooling and warming on patients undergoing rehabilitation processes.

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