# Effect of Heat in Conjunction with Stretching in Promoting Flexibility of Thigh Muscles in Athletic Subjects

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## ABSTRACT

*The purpose of this study was to investigate the combined effect of superficial heat and passive stretching in promoting the flexibility of the quadriceps and hamstrings of athletic male subjects. Twelve male athletes of an age ranging between 20 and 31 years had their hip range of motion measured twice as an index to variation in muscle extensibility. Firstly after having been only mechanically passively stretched and secondly after having received 20 minutes of hot pack application with the same passive stretching procedure being applied immediately after the heat application. The results of these two measurements were then compared and analysed, with the results showing that a combination of heat and passive stretching achieved a significantly larger increase in range of hip flexion and extension than passive stretching only. The implication of these results are discussed with respect to any condition or activities where increased range of movement might be of benefit.*

## INTRODUCTION

Maintaining a reasonable degree of flexibility in athletic subject is necessary for efficient body movement. Being flexible may decrease the chances of sustaining muscle injury and muscle soreness. To move body segments, the muscles opposite those performing the movement must lengthen sufficiently. Tight musculature and associated connective tissue limit lengthening of the antagonistic muscles and thus reduces the range of motion (ROM) of body segments. Moreover, soreness or injury may result when tight musculature is subjected to strenuous physical activity[9].

Heat in various forms is possibly the oldest treatment modality still in use, for a variety of conditions. Clinically, the use of superficial heat modalities in rehabilitation after upper limb fractures is a common adjunct to other treatment methods and exercises, including stretching. It therefore appears reasonable to assume that when linking a superficial heat modality with any form of stretching, a possibility of increasing ROM seems not only likely, but should in fact increase ROM more than stretching alone. Investigations on the combined effect of both heat and stretching demonstrated that superficial heating and passive stretching of the hamstrings increased range of hip flexion motion more than passive stretching alone[4,11].

According to Lehman and de Lateur[8] superficial heating among other modalities including passive stretching can increase the extensibility of collagen tissues, decrease joint stiffness and reduce muscle spasm. All of which are factors that would appear to increase the possibility of achieving greater ROM. In addition, passive stretching results in a sustained muscle-tendon unit elongation, due to the visco-elastic properties of the muscle[13].

Taylor et al.,[13] investigated the viscoelastic properties of the muscle tendon unit and the biomechanical effects of stretching. Muscle tissue has both elastic and viscous properties, therefore they are generally termed visco-elastic. The authors took muscle tendon-units from the extensor digitorum longus muscle and the tibialis anterior muscle of several rabbits and exposed them to three forms of stretching. Experimental techniques simulating cyclic and static stretching, the effects of various stretch rates and reflex activity in response to stretching was evaluated. Cyclic and static stretching resulted in a sustained muscle-tendon unit elongation, with the researchers claiming that the length increase that occur with stretching is due to visco-elastic properties of the muscle-tendon unit. The study also found that the first four stretches were responsible for nearly all the elongation during the static stretching. After the first four stretches no significant elongation of the muscle-tendon unit was found. Another finding was that most of the elongation takes place between the first 12 to 18 seconds of a stretch interval in comparison to the second time interval of 12 to 18 seconds, where no further significant increase in length was found. In addition the authors stated that reflex activity did not influence the biomechanical characteristics of the muscle-tendon unit.

The clinical relevance of the above study suggests that stretching will result in greater flexibility of the muscle due to its visco-elastic nature and also greater flexibility at the joint the muscle crosses. This will ultimately lead to greater ROM at the joints, which is beneficial in all forms of rehabilitation where increased ROM is important. This also suggests that four repetitions of passive stretching should be enough to achieve maximum elongation of the visco-elastic properties of the muscle and that the duration of these stretches need not exceed 18 seconds to produce an optimum lengthening of the muscle. The last finding[13] to consider, is the fact that with faster stretch rates, like in ballistic type stretching, greater tension at the muscle-tendon unit was created. This increases the likelihood of strain injuries from overstretching and shows that the rate of stretching and not the technique, is the more likely cause of stretch related injuries.

The work of Taylor et al.,[13] considered the biomechanical aspects of stretching, whereas several studies have investigated the effects of reflex activity in response to stretching and ways to overcome these in order to achieve greater ROM[1,9,12]. Investigation into the reflex responses of the muscle spindle and the Golgi tendon organ (GTO) to stretch demonstrated that muscle spindle initiates a stronger reflex contraction of the stretched muscle to reduce stretch, thus protecting the muscle against overstretching[9]. To overcome this reflex response it was suggested that yoga - style stretching, i.e. static stretching, only produces a weak muscle spindle stretch reflex[12]. Therefore, it seems reasonable to assume that slowly initiated stretching techniques like passive and static stretching would overcome the muscle spindle reflex, allowing greater elongation of the muscle with increased ROM as a result.

The GTO responds to tension created in the muscle during both shortening and lengthening[1]. Further, the function of the GTO is to protect the muscle from injury caused by an excessive load. Should the muscle be excessively stretched the GTO will trigger a reflex inhibitory response that will relax the muscle and therefore achieve greater length than it originally possessed. This means that a prolonged stretch as in passive or static stretching will relax the muscle due to the response of the GTO, allowing it to lengthen to prevent overstretching and eventually achieve greater ROM at the joint the muscle crosses.

Normally muscle tendons are essentially visco-elastic in nature with the elastic properties predominating. Therefore, when a tendon is subjected to stress it will elongate and return to its normal length once the force is removed[8]. Investigating the effect of temperature on tendons showed that with increased temperature the viscous properties of the tendon became dominant. It was reported that with an increased load (stretching) applied to a tendon at 45 C degrees the elongation of the tendon was not only increased, but the tendon remained elongated after the load was removed. When the load was applied without an increase in temperature no change in tendon length was observed[8].

The use of superficial heat combined with stretching in the lower limb of atheletic individuals appears relatively limited, in both clinical experience and research literature. Therefore, the purpose of this study emerges, to investigate the combined effects of superficial heat and passive stretching on the ROM of the lower limb of atheletic subjects.

## METHOD

### *Subjects*

Twelve atheletic subjects were randomly selected from a Sporting Club of a residential area. All subjects were male aged between 20 and 31 years and with an average of 24 ± 3.2 years. Their weight ranged between 59 and 84 kgs. Timprove the reliability of the study the chosen subjects were all right foot dominant. The subjects were informed thoroughly on the aspects concerning their participation in the tests and then all subjects agreed to take part in the study on a voluntary basis. All subjects declared that they were free from any orthopaedic dysfunctions of the hip and knee. They were all healthy at the time of testing and completely free of any medical problems like hypersensitivity and allergic skin reactions to heat. All 12 subjects had normal cutaneous sensation. Prior to the study the subjects were informed that their participation in the study required that they were tested twice in three days at approximately the same time of day. They were also instructed not to take part in any physical activity 48 hours before the test.

### *Materials*

1- A pulley system with suspended weights was used to produce mechanical static passive stretching for the quadriceps and hamstrings muscle group.
2- A standard goniometer was used to measure the range of hip movement and a skin marker provided the surface markings on the skin of each subject used as reference lines for the goniometric measurements.
3- Two knee braces were used on both legs of each subject to lock their knees in the

position desirable for each of the two tests the subjects underwent.

4- Two cold/hot gel packs were used for the heat application. According to the manufactures instructions, the hot pack gain a temperature of between 41 and 45?C after 5 minutes of being placed in boiling water. Before being placed on the subjects the hot packs were each wrapped by a cotton towel before being applied to the skin of the subject.

5- A bathroom scale was used to measure the weight of each subject. Ten percent of the subject's body weight was then calculated to find the amount of weights that were to produce the mentioned stretching force.

## PROCEDURE

Hip flexion ROM was measured using a modified straight leg raise procedure (the knee of the tested leg locked in extension). This position was chosen because passive insufficiency of the hamstrings will insure that maximum stretch is achieved[2]. The right leg was fixed to a pulley system, via an ankle cuff just proximal to the ankle, with suspended weights at the end, while the contralateral leg was securely fixed to the bed with a velcro strap. The right leg was then passively raised by the suspended weights, which measured 10% of the subject's body weight. The load was applied very slowly by the examiner. The slow loading was done to prevent unwanted stretch reflexes and the subject was instructed to relax during the 10-15 seconds it took before the full load was applied. At the instant the load was fully applied, the examiner took the first measurement of hip flexion which was referred to as the pre-test hip flexion measurement.

The subject was then given two minutes rest before the above mentioned procedure was repeated. This time however the right hip was held in full flexion for one minute, with the second measurement taken at the end of the 60 seconds. Subjects were instructed during the 60 seconds of stretching to relax and let the force of the weights stretch the hamstrings. Taylor et al.,[13] stated that up to 60 seconds of passive stretching is the recommended time to expose muscles to stretch. The load was slowly removed after the passive stretch and the subjects were allowed to rest in a neutral position for two minutes. This procedure was repeated another two times with each subject. The mean result from these three measurements was used in the statistical analysis.

For measurement of hip extension ROM a modified Thomas test procedure was used, as described by Godges et al.,[2]. The Thomas test is normally used to measure the length of the quadriceps muscle and it appears ideal for the purpose of this study because it places the quadriceps muscle under maximum tension due to passive insufficiency. The two leg braces both locked the knees at 90? flexion. Both hips were then flexed to the trunk, to the point where the lumbar spine was flat on the bed and with the left leg being securely fixed in this position with a velcro strap. This was done to prevent unwanted movements, like an increased lumbar lordosis, which may influence the ROM. A load of 10% of the subjects body weight was then applied around the right thigh, midway between the anterior superior iliac spine and upper border of patella via a strap. The subject was placed near the end of the bed so that the hip was allowed to be pulled freely into extension by the pull of the weights. The load was applied slowly over a period of 10-15 seconds and the first measurement was taken. This first measurement is referred to as the pre-test hip extension measurement. Then as with the procedure undertaken for hip flexion measurements the subject was given 2 minutes rest and then the load was slowly applied for 60 seconds. At the end of the 60 seconds the measurement of hip ROM extension was then taken followed by two minutes rest. This procedure was repeated another two times so that three measurements of hip extension ROM were obtained and a mean measurement was calculated for analysis.

To measure the combined effect of heat and passive stretching the exact same stretching procedures as before were repeated. One hot pack was applied to the quadriceps muscles, 10 cm above the upper border of patella on the anterior aspects of the right thigh, before measuring hip extension ROM. Before measuring hip flexion ROM the hot pack was applied to the hamstrings muscles 4 cm beolow the ischial tuberosity on the posterior aspect of the right thigh. In both cases the hot packs were applied in midline positions.

To achieve maximum heating effects as described by Halvorsen[3] the hot packs were replaced after 10 minutes, with both the quadriceps and the hamstrings muscles receiving a total of 20 minutes heat application before the passive stretching. The hot packs were removed after 20 minutes with the passive stretching procedure described above being initiated immediately after.

Once the test procedure of heat and passive stretching was completed the subject rested for 30 minutes before the heat was reapplied to the opposite muscle group and the test procedure repeated for measurement of the opposite ROM. This was done to diminish the generalised rise in temperature that follows local heating, due to the earlier mentioned physiological effects of heat.

To diminish the so called order effect, i.e. that the results could have been affected by the order in which the tests were carried out counterbalance was used. This meant half the subjects underwent test A (passive stretching) first and then test B (heat and passive stretching), whilst the order of testing involving the other half of the subjects was reversed. To counterbalance even further the subjects that had their hip flexion measured first during test A (passive stretching) had their hip extension measured first on test B (heat and passive stretching).

All the procedure and tests of the study were carried out by the same examiner in the physiotherapy clinic of the sporting club with a room temperature 25? centigrade.

## RESULTS

Table 1 and 2 shows the mean of three measurements of ROM achieved by the 12 subjects on each of the 8 tests they had to take part in. The ROM increased from the two initial measurements, seen as the pre-test hip ROM, that were taken before the actual passive stretching and the heat and passive stretching were initiated. Both the hip flexion and extension ROM increased with every session of passive stretching with or without the application of heat.

***Table (1): Range of Hip Flexion (measured in angular degrees)***

| Test | Passive Stretching | Heat + Passive Stretching |
|---|---|---|
| Pre-test hip ROM | 94.17 ± 8.6 | 94.67 ± 8.75 |
| 1st Post-test hip ROM | 96.5 ± 7.88 | 97.75 ± 8.32 |
| 2nd Post-test hip ROM | 97.9 ± 8.12 | 100.25 ±8.03 |
| 3rd Post-test hip ROM | 99.75 ± 7.66 | 101.25 ± 7.78 |

Mean ROM in degree ± 1Sd.

***Table (2): Range of Hip Extension (measured in angular degrees).***

| Test | Passive Stretching | Heat + Passive Stretching |
|---|---|---|
| Pre-test hip ROM | 15.25 ± 4.1 | 15.1± 3.58 |
| 1st Post-testhip ROM | 16.83 ± 3.64 | 97.75 ± 8.32 |
| 2nd Post-test hip ROM | 17.75 ± 3.52 | 19.08 ± 3.61 |
| 3rd Post-test hip ROM | 19.08 ± 3.68 | 20.25 ± 3.28 |

Mean ROM in degree ± 1Sd.

To find if these increases in hip ROM were significant, irrespective of the heat application, the one tailed related t-test was used[5]. This was done to compare the mean pre-test range of hip flexion and extension against the mean from the three hip flexion and extension ROM measurements, taken after each session of passive stretching. These results are shown in table 3 and 4.

Inspection of table 3 and 4 shows that both passive stretching alone and heat in conjunction with passive stretching significantly increased the range of both hip flexion and extension. The results presented above clearly demonstrate that the range of hip flexion and extension significantly improved with both passive stretching alone and a combination of heat and passive stretching. Therefore, a comparison between the two conditions was necessary to investigate if one of the two conditions (passive stretching alone or passive stretching in conjunction with heat) would produce a better result than the other. Using the related t-test a statistical comparison was made between the mean increase in the hip ROM after passive stretching alone and after heat plus passive stretching (table 5). The results showed that the range of hip flexion and extension increased significantly more with heat and passive stretching than with passive stretching alone (see also figure1).

***Table (3): Range of Hip Flexion (in degrees)***

| Test | Mean Pre-test | Mean Post-test | Related t-test | Probability |
|---|---|---|---|---|
| Passive Stretching | 94.17 | 98.05 | 4.13 | P < 0.05 |
| Heat + Passive Stretching | 94.67 | 99.86 | 4.61 | P < 0.025 |

***Table (4): Range of Hip Extension (in degrees)***

| Test | Mean Pre-test | Mean Post-test | Related t-test | Probability |
|---|---|---|---|---|
| Passive Stretching | 15.25 | 17.89 | 4.04 | P < 0.05 |
| Heat + Passive Stretching | 15.1 | 18.83 | 4.16 | P < 0.025 |

***Table (5): Mean increase in hip range of movement (in degrees).***

| Test | Mean Increase Stretching only | Mean Increase Heat + stretching | Variance | Related t-test | Probability |
|---|---|---|---|---|---|
| Hip Flexion | 3.89 | 5.11 | 1.22 | 4 | P < 0.00 |
| Hip Extension | 2.64 | 3.72 | 1.08 | 3.103 | P < 0.01 |

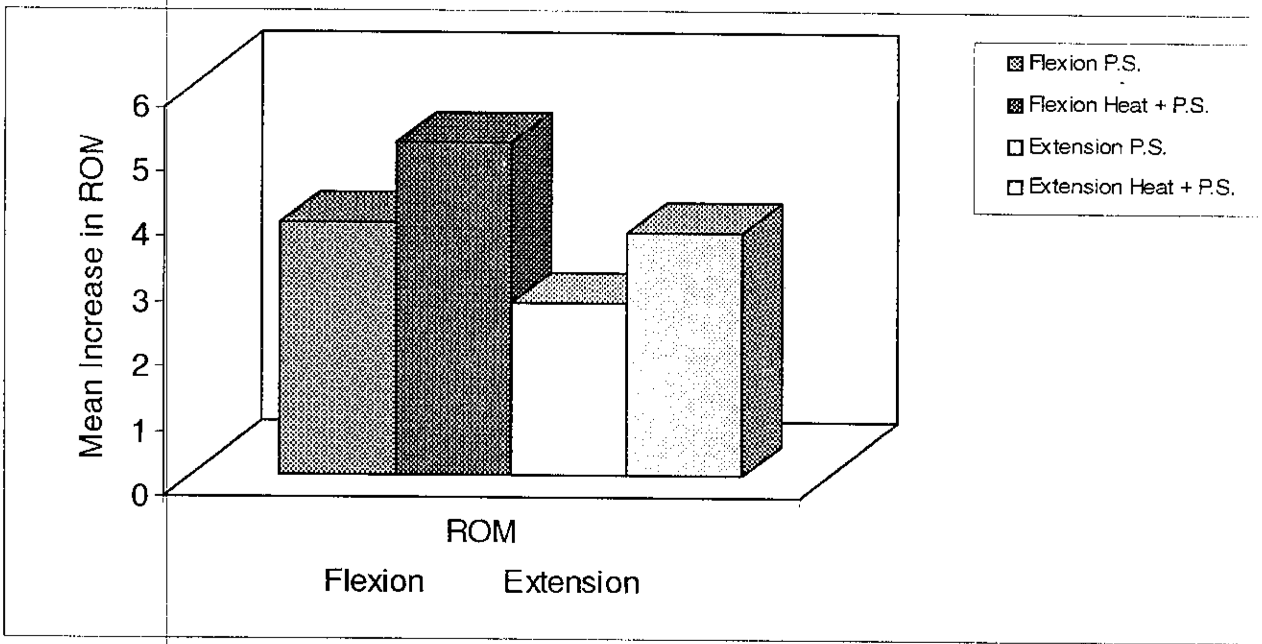


*Fig. (1): Mean increase in range of hip motion.*

## DISCUSSION

The results of this study indicated clearly that ROM at the hip increased more with the application of heat to muscles before passive stretching than with passive stretching alone. These results are in accordance with those of Henricson et al.,[4] who found that heat alone did not increase hip ROM, whereas passive stretching increased hip flexion and external rotation. Heat and passive stretching gave the greatest increase in hip flexion, and also increased hip abduction.

Other studies by Wiktorsson-Moller et al.,[14] and Hubley et al.,[6] have also found that heat increased ROM , but the chosen heat modality for these studies has usually been warm-up and exercise, which produces a much deeper heating effect than a superficial heat pack. They can therefore not be considered as totally relevant comparisons to this study, although their results appear to strengthen the theoretical support to the findings even further.

The work of Michlowitz[11] also supports the view that heat and passive stretching are more efficient than stretching alone in increasing hip ROM. The author found that hamstring stretching after superficial heating increased hip flexion more than passive stretching alone. In addition, Lehmann and de Lateur[8] have earlier reported that the extensibility of collagen tissues increases with increased temperature. That provides some theoretical support for the findings in this study.

Mense[10] pointed out that heat relieves muscle spasm, which in turn would allow for greater ROM. He explained that the relief in muscle spasm is due to decreased firing rate from the muscle spindle and increased firing from the Golgi tendon organ.

The findings of Taylor et al.,[13] regarding the biomechanical effects of stretching provide further support to this study. The authors found clear evidence that static passive stretching caused a prolonged muscle-tendon unit elongation. They explained their results on the finding that muscle tissue is visco-elastic in nature, thus being able to increase in length when exposed to various loads like in passive stretching. Furthermore, Lehmann and de Lateur[8] stated that tendons when exposed to temperatures between 41?C and 45?C change their behaviour, from being predominantly elastic to predominantly viscous. From this it seems reasonable to assume that heat and passive stretching in combination should increase hip ROM more than passive stretching alone. With increased viscosity the tendons would remain in the sustained state of elongation which they were placed in by the load of the stretching force, as opposed to when the elastic properties predominate ensuring that the tendons return to their resting length when the stretching force is removed.

One limitation of this study is that all the subjects were atheletic and all were quite used to stretching. This could mean that the increase in hip ROM found could be different than it would be in a population with people who are less used to stretching. In addition, all subjects were young, fit and healthy without any excessive body fat that could affect hip ROM. However, a reasonable assumption could be made that many patients would actually increase their ROM with heat and passive stretching as is the case with atheletic subjects. In addition heat if is not used as the only treatment modality, it should at least be a very useful adjunct to other therapeutic modalities in the rehabilitation of joints with limited ROM. More specifically, it seems obvious that in rehabilitation after fractures and other orthopaedic problems, with or without surgical intervention, the use of heat and passive stretching should have a place.

## CONCLUSION

This study showed clearly that passive stretching significantly increases ROM at the hip in young healthy male atheletes. In addition superficial heat in combination with passive stretching increases the range of hip movement more than passive stretching alone in young healthy males. It therefore seems reasonable that physiotherapists involved with atheletic subjects, should bear this in mind if involved with flexibility training aimed at increasing ROM and also when involved with other pathological conditions where an increase in ROM woul be of benefit.

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## الملخص العربي

## تأثير الحرارة المتزامنة مع التمديد في تيسير مرونة عضلات الفخذ في الأشخاص الرياضيين

يهدف هذا البحث إلى معرفة تأثير الحرارة السطحية المتزامنة مع الاستطالة القصرية في تيسير المرونة لعضلات الفخذ في الرياضيين من الرجال . اشترك في هذا البحث اثنا عشر من الرياضيين الرجال تتراوح أعمارهم بين ٢٠ - ٣١ سنة . وقد تم قياس مدى حركة مفصل الفخذ مرتين الأولى بعد التمديد الميكانيكي فقط والثانية بعد استخدام الكمادات الساخنة الموضعية لمدة ٢٠ دقيقة تبعها التمديد القصري مباشرة . ثم تمت مقارنة القياسين وتحليلهما . وقد أظهرت نتائج الدراسة أن استخدام التسخين السطحي المتزامن مع التمديد القصري يفوق التمديد القصري فقط بمدى كبير ذو دلالة احصائية في زيادة مدى كلا من حركتي الثني والفرد لمفصل الفخذ . وقد أكدت الدراسة أهمية استخدام هذه الطريقة في الحالات التي تحتاج لزيادة مدى الحركة لأى من المفاصل سواء أصحاء أو مصابين .