Original Article

ผลของระยะเวลาในการประคบด้วยความร้อนตื้นต่อความสามารถในการยืดออกของกล้ามเนื้อน่อง

ประเสริฐ สกุลศรีประเสริฐ*
มัณฑนา วงศ์ศิรินวรัตน์
จุติพร ธรรมจารี
ดวงธิดา ขอบเหลือง
กฤติยา สุนทรวิริยะวงศ์

Effect of Superficial Heating Duration on Plantarflexor Extensibility.

Prasert Sakulsriprasert, Mantana Vongsirinavarat, Chutiporn Thammajaree, Duangthida Khoblueng, Kritiya Sunthornwiriyawong

Faculty of Physical Therapy, Mahidol University, Salaya, Nakhonpathom, 73170, Thailand

*E-mail: ptpsk@mahidol.ac.th

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บทคัดย่อ:

วัตถุประสงค์: การศึกษานี้ทำการเปรียบเทียบผลของระยะเวลาในการประคบด้วยความร้อนตื้นที่กล้ามเนื้อน่องต่อความสามารถในการยืดออกของกล้ามเนื้อ

วัสดุและวิธีการ: ผู้เข้าร่วมการทดสอบสุขภาพดีจำนวน 75 ราย ได้รับการสุ่มเพื่อแบ่งออกเป็น 3 กลุ่ม คือ กลุ่มควบคุมซึ่งไม่ได้รับการประคบร้อน กลุ่มที่ได้การประคบร้อน 15 นาที และกลุ่มที่ได้การประคบร้อน 30 นาที โดยทำการประคบที่กล้ามเนื้อน่อง ผู้วิจัยวัดค่าความสามารถในการยืดออกของกล้ามเนื้อน่องเป็นค่าองศาการเคลื่อนไหวของข้อเท้าก่อนและหลังการประคบโดยทันที

ผลการศึกษา: กลุ่มที่ได้รับการประคบ 15 นาที มีค่าองศาการเคลื่อนไหวที่เพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติเมื่อเทียบกับกลุ่มควบคุมและกลุ่มที่ได้รับการประคบ 30 นาที

สรุป: การประคบด้วยความร้อนตื้นมีผลช่วยให้กล้ามเนื้อยืดเหยียดออกได้ดี โดยในการศึกษานี้เสนอแนะว่าระยะเวลาที่ใช้ในการประคบมีผลต่อความสามารถดังกล่าว โดยระยะเวลาการประคบที่ 15 นาที มีความเหมาะสมต่อการเพิ่มองศาการเคลื่อนไหว

คำสำคัญ: กล้ามเนื้อน่อง, แผ่นประคบร้อน, ระยะเวลา

คณะกายภาพบำบัด มหาวิทยาลัยมหิดล อ.ศาลายา จ.นครปฐม 73170
รับต้นฉบับวันที่ 20 กรกฎาคม 2553 รับลงตีพิมพ์วันที่ 2 พฤศจิกายน 2553

Abstract:

Objectives: This study aimed to compare the immediate effect of different durations of superficial heating on the extensibility of the plantarflexors.

Materials and methods: Seventy-five healthy subjects were randomized into one of 3 groups: no heating (control), 15-minute superficial heating, or 30-minute superficial heating. Ankle dorsiflexion active range of motion (AROM) in the lunge position was used as the indicator of plantarflexor's extensibility, with the lunge position tests performed before and immediately after the intervention.

Results: Immediately after the 15-minute heating intervention, the ankle dorsiflexion AROM was significantly increased in this group. The control and 30-minute heating groups did not have any increase of ankle dorsiflexion AROM.

Conclusion: Superficial heating in the form of hot pack application proved to have an immediate effect in increasing plantarflexor muscle extensibility. The 15-minute application of heating improved the degree of ankle dorsiflexion. This study proposed that 15 minutes of heating was effective in increasing dorsiflexion AROM in healthy subjects.

Key words: calf muscle, duration of heating, hot pack

Introduction

Heating modalities are widely used among physical therapists for therapeutic purposes including pain relief, muscle relaxation, and blood-flow and tissue-healing facilitation.[1-5] Many biophysical effects of heating have been proven such as metabolic reactions,[6] vascular effects,[1,3,6-8] neuromuscular effects,[3,9] and connective tissue effects.[10,11] Physical therapists use heating modalities to increase tissue extensibility, frequently in combination with stretching, in order to improve mobility.[5,10-12] The increase of tissue extensibility has also been noted with connective tissue effects[10,11] and altered neuromuscular control.[3,9]

Heating alternatives can mainly be divided into superficial heating and deep heating based on depth of penetration of each heating modality. The superficial heating modalities include, for example, hot pack, paraffin wax bath, fluido-therapy, and electrical heating devices. The main deep heating modalities are short-wave diathermy, and continuous-wave ultrasound. Superficial heating can increase tissue temperature to 1-3 cm depth, while deep heating can penetrate from 1-5 cm.[3,5] Deep heating is therefore appropriate for deeper structures such as joints or deep muscles. However, the use of deep heating modalities has more contraindications than superficial heating devices, and thus more precautions must be observed when using this treatment.[5,13-15]

Superficial heating such as applying a hot pack has fewer restrictions and is more frequently used. Physical therapists commonly apply hot packs in order to provide pain relief and promote tissue

extensibility for 15-30 minutes,[3,5,16-19] following the provided instructions. However, Lehmann and deLateur[3] suggests that hot pack application lasts 20-30 minutes as a general technique. While, the previous research, the hot pack application of 15 minutes was used to increase ankle dorsiflexion AROM.[19] So, it is unknown whether 30 minutes or 15 minutes would be better in increasing tissue extensibility.

Normally the elevation of tissue temperature to be between 40-45 °C is considered as the therapeutic range with the presence of hyperemia.[3] For deep heating modality, it has been reported that at least 5 minutes of heating is needed for tissue extensibility improvement,[20] but, there have been no studies on the optimum duration of superficial heating application for significant tissue extensibility improvement.

Anyhow, from the previous study, it was found that muscle temperature rose up sharply in the first 15 minutes, and then the temperature is plateau after 15 minutes until 30 minutes in subjects that were applied a topical superficial heating of 30 minutes.[6] The previous study reported only the change of temperature in skin, subcutaneous tissue, and muscle, it was unknown whether the duration of superficial heating application affects the tissue extensibility or not? Therefore, from this knowledge, it is interesting to study whether the duration of 15 or 30 minutes of superficial heating application is more effective on tissue extensibility.

This study was therefore undertaken to investigate the effect of different durations of superficial heating on tissue extensibility, using the plantarflexor function as the focus of study, as this is a common problem area where superficial heat is commonly applied. There were three groups: no heating, 15-, and 30-minute heating. We hypothesized that a 15-minute heating regime would show a greater increase in plantarflexor extensibility compared to no heating and that a 30-minute heating application would show a greater increase in plantarflexor extensibility than a 15-minute heating.

Materials and methods

This research was an experimental study to compare before and immediately after the use of superficial heating in three groups; no heating, 15-minute, and 30-minute applications. The study proposal has been approved by Mahidol University Institutional Review Board (MU-IRB), Mahidol University, Thailand.

Subjects

From sample size calculation for Analysis of Variance (ANOVA) with f is 0.4, power is 0.8, and degree of freedom is 2, the sample size is 21 subjects per group.[24] So, the subjects were recruited up to 25 per group in order to compensate 20% loss due to dropouts. Therefore, 75 healthy subjects (45 women, 30 men) were totally recruited for 3 groups with an age range from 18-25 years, which all of subjects were from Faculty of Physical Therapy, Mahidol University. The characteristics of all subjects are demonstrated in Table 1. The subjects were excluded if they had 1) any obvious musculoskeletal or neurological problems affecting their lower extremities, 2) metal implants in their lower extremities, 3) sensory impairment or neural

tension at the lower extremities, 4) restriction of ankle motion, 5) fever, 6) pregnancy, 7) skinfold thickness over 1 cm at calf muscle area measured by Vernier caliper, 8) being athletes or performing heavy activity, or 9) any medical conditions that could be aggravated by superficial heating.

Procedure

All 75 eligible subjects who passed the interview and physical examination screening for participation gave informed consent. Then, they were tested for their dominant leg with 3 tasks: kicking a ball, drawing the number eight with their foot, and grasping a pen with their toes. This dominant leg was the one which would be used as the test leg. Every subject was interviewed about their daily living activities with a brief questionnaire to ensure that the subjects were not athletes and did not regularly perform heavy activities using their legs before the study.

The extensibility of the plantarflexor, in this study, was tested in the weight-bearing lunge position. Prior to the study, the ankle dorsiflexion active range of motion (AROM) was measured and used as baseline data as an indicator of the plantarflexor extensibility. The extension measurements were taken 3 times, with the highest value obtained then used as a baseline ankle dorsiflexion AROM.

After the baseline measurements were obtained, the subjects were randomly divided into 3 groups by drawing lots to assign into a group, with the single intervention of ensuring a similar gender-match quota in each group. Each group contained 25 subjects. The measurement researcher was blinded to subject division and intervention application. After baseline measurement, the subjects were allowed to take a rest up to 30 minutes if needed to dissipate any discomfort sensation during the baseline measurement might cause before their intervention was performed. After they rested, they underwent according to the designated group: no heating, 15-minute heating, or 30-minute heating. After the intervention, their ankle dorsiflexion AROMs were immediately measured, again 3 times, with the highest value recorded.

Interventions

Subjects in the no heating group did not undergo any heating intervention. They were positioned supine on a bed, and asked to remain in this position for 30 minutes.

Subjects in the 15-minute heating group were asked to be in a supine lying position for 15 minutes first, and then the intervention provider placed a new 27.5 x 27.5 x 1 cm hot pack (MES trading, Thailand) covered with 2 layers of toweling under the calf muscle area of the subject's test leg, beginning from the inferior border of the popliteal fossa and extending towards the foot. The heating intervention was applied for 15 minutes.

Subjects in the 30-minute heating group were in a supine lying position and received the same hot pack procedure as the 15-minute group except they had the pack applied for 30 minutes continuously.

Subjects in the 15- and 30-minute heating groups were instructed to keep the same position and not to raise their legs off the hot pack. To

maintain this position, they were informed that their perception of heat during their treatment should be comfortably warm only, not too strongly warm or hot, and if they felt that their hot pack was more than comfortably warm, more toweling was offered immediately. All subjects were instructed to inform the intervention provider at any time during their treatment to adjust the toweling to maintain optimum warmth. A thermometer was inserted directly on to the hot pack surface to monitor the temperature for the whole period of heating. After the 15- or 30-minute session was finished, the hot pack was removed and the subject stood up slowly and went for their dorsiflexion test. The hot packs used in this study were preheated for a minimum of 24 hours in a hot-pack heater at 80 ^{o}C. The treatment room temperature was maintained at 25 ^{o}C.

Ankle dorsiflexion AROM measurement

The testing protocol was adapted from a study done by Robertson et al.[19] in which the previous studies reported intratester reliability ranged from 0.94-0.98.[21,22] The ankle dorsiflexion AROM representing the plantarflexor extensibility was measured with an inclinometer. The inclinometer was calibrated before use, and was then placed on a horizontal surface and then zeroed. The test position was the weight-bearing lunge position, in which the test leg is placed behind the subject in a straight position, while the another leg is in the front with the knee bent. Before the study, the measurement researcher had practiced many times to become fully familiar with the device and the measurement protocol; the intratester reliability was assessed with $ICC_{3,3}$ of 0.97.

Before the measurement, the subject was marked with a whiteboard marker at the midline between the inferior border of the patella and the anterior ankle joint line. This mark was used for inclinometer placement.

To perform the test, the subject was first asked to face the wall with their hands touching the wall to help them maintain balance. The other foot was comfortably placed in front of the test leg, the knee bent. The subject's body was in a neutral position. To begin the test, the subject was asked to extend the test leg backwards as far as possible with the knee kept straight with the heel fully flat on the floor, and the foot in the neutral position. The researcher kept monitoring the subject's position to ensure they made no compensatory movements at any joints such as heel lifting off, ankle or leg rotation, knee bending, foot pronation or supination. Every subject was given the same instruction "Move your test leg backward as far as possible until your calf muscle is fully stretched with the knee straightened, the heel flattened fully, and the foot neutrally aligned". The subject kept the other leg, in the front, bent in order to allow the test leg to move backwards and to keep their balance.

The researcher then placed the inclinometer on the marked line of the subject's shin when the subject said they could not go any further and their position was stable. The researcher adjusted the inclinometer to the new angle, which they recorded. The measurement took less than 10 seconds, after which the subject was told to return to a normal upright position for 1 minute

before the second test was done, and then the third, following the same protocol. Of the 3 tests, the highest value was used for the subject's ankle dorsiflexion AROM. During the test process, the measurement researcher was blinded as to which of the three groups the subject belonged to.

Data analysis

All statistical analyses were done using SPSS program for Windows, version 13. The Kolmogorov-Smirnov Goodness of Fit-test showed that the data was distributed normally. ANOVA was used to compare changes in three groups. If a statistically significant difference was found, the Bonferroni test was further used for post-hoc analyses. The level of statistical significance was set at $p<0.05$.

Results

Subjects' characteristics

The subjects' characteristics regarding age, weight, height, and BMI are shown in Table 1. The baseline data of ankle dorsiflexion AROM in three groups was similar without statistical significance (F=0.543, P=0.583).

Between-groups analysis

The values of baseline (pre), after intervention (post) and changes in ankle dorsiflexion AROM are shown in Table 2. The ANOVA showed a statistically significant difference in the changes among the three groups (F=4.539, P=0.014).

The Bonferroni post-hoc test indicated a statistically significant difference in 2 of 3 comparisons. The change in ankle dorsiflexion AROM between the no heating group and the 15-minute group was significantly different (P=0.027). Also, the change in ankle dorsiflexion AROM between the 15-minute group and the 30-minute group was significantly different (P=0.041). But there was no significant difference between the no heating group and the 30-minute heating group.

Table 1 Subjects' characteristics (n = 75 totally, 25 of each group)

Baseline characteristics	No heating	15-minute	30-minute	P-value
Gender (female: male)	15:10	15:10	15:10	1.000
Age (years)	21.08 (1.4)	21.29 (1.4)	20.95 (1.2)	0.690
Weight (kg)	53.92 (6.59)	54.74 (8.70)	54.16 (7.93)	0.933
Height (cm)	163.87 (6.66)	163.62 (6.78)	163.95 (8.07)	0.986
BMI (kg/m^2)	20.05 (1.58)	19.81 (1.76)	20.09 (2.13)	0.853

Data presented in means and (SD). There was no statistically significant difference between groups calculated by ANOVA as shown in p-values.

Table 2 Ankle dorsiflexion AROM before and after the intervention in the three groups

Time of measurement	No heating	15-minute	30-minute	P-value
Baseline (pre)	42.32 (4.05)	40.56 (6.90)	41.24 (6.68)	0.583
After intervention (post)	42.60 (4.85)	43.52 (7.02)	41.68 (7.38)	0.610
Change (post-pre)	0.28 (2.11)	2.96 (3.63)	0.44 (4.43)	0.014*

Data presented in means and (SD).

Temperature

The temperature of the hot pack did not fall below 45 degrees Celcius throughout the duration of the experiments in both 15-minute and 30-minute heating groups.

Discussion

Heat modalities are used by physical therapists worldwide for pain alleviation and tissue extensibility promotion.[5] However, information regarding the optimum duration of heating is unknown. The duration of fifteen or thirty minutes is generally prescribed by physical therapists for their patients for increasing tissue extensibility.[6] This study therefore aimed to investigate the efficacy of different durations of superficial heating on the plantarflexor extensibility.

The findings showed that a 15-minute heating application significantly increased ankle dorsiflexion AROM in healthy subjects. There was no significant difference found in 30-minute heating group and no heating group. The significant increase in the 15-minute heating group corresponded to the study of Robertson et al.[19] Their study examined only a 15-minute application of superficial heating, and found that ankle dorsiflexion AROM increased significantly with heating compared with no heating. In the Robertson study, the mean change of ankle dorsiflexion AROM was $0.7^{o}\pm1.5^{o}$ and the post-heating ankle dorsiflexion AROM was 34.7^{o}-37.5^{o}. The present study showed greater figures for both mean change and post-heating ankle dorsiflexion AROM of $2.96^{o}\pm3.63^{o}$ and $43.52^{o}\pm7.02^{o}$, respectively. Our greater values might be because this study did not use a wooden wedge for foot placement during measurements, which was used in the Robertson study.[19] However, both this study and the Robertson one had the same results in finding that a 15-minute superficial heating application had an immediate effect on ankle dorsiflexion AROM increment in healthy subjects.

The improvement of ankle dorsiflexion AROM with heat treatment is due to the effects of heating on connective tissues and neuromuscular control. The elevation of temperature changes the viscoelastic properties of connective tissues 10 and also effects the muscle spindle firing rate,[23] enhancing the ability of the muscles to stretch resulting in muscle relaxation and increased extensibility.

Surprisingly, we did not find that a 30-minute heating application increased ankle dorsiflexion AROM even more than the 15-minute application. To try and understand this, we examined the data from the 30-minute group more closely. We found that 44% (11 subjects of 25) of these subjects showed decreased ankle dorsiflexion AROM immediately after heating, and these subjects had also complained about an uncomfortable sensation at their calf during the post-heating measurements.

The insufficient warmth towards the end of the 30-minute heating could be refuted as a factor, because the records we kept confirmed that the heat generated by all of the hot packs remained in the therapeutic range of 40-45 °C as proposed by Lehmann and deLateur[3] for the full 30 minutes. Also, the subjects had been instructed to inform the intervention provider to adjust the toweling for optimum warmth for the entire duration of heating. All subjects in both the 15- and 30- minute heating groups responded to the researchers that they felt comfortably warm for the entire duration of heating with no adjustments of toweling requested.

The results in the 30-minute heating group may indicate that 30 minutes of heating is over the optimum duration, and the excessive heat might disturb the plantarflexor extensibility immediately after heating. The disturbance during measurement was in form of discomfort sensation when the subjects performed full stretching for measurement, while this discomfort did not appear at rest. However, we did not study the longer term effects which may have a better result. This point was a limitation of our study.

The lack of tissue temperature measurement was another limitation. We monitored the temperature of the hot pack throughout the time of application, but not the tissue temperature; this was because our subjects were healthy sedentary people, and our focus was not on tissue healing, for which tissue temperature elevation to between 40-45 °C is considered as the therapeutic range. Future studies involving tissue healing investigation, with tissue temperature measurement, are strongly recommended.

In this study, all subjects were interviewed about their activities of daily living, so we could be sure that the subjects were sedentary people who did not perform heavy activities which could have an effect on our measurements. Therefore, interpretations of the results are applicable mainly to healthy, sedentary people in the age range of 18-25 years. We also did gender matching to ensure each group had a similar female: male ratio, even though the Robertson study indicated that gender effects on plantarflexor extensibility can be ignored.[19]

The lunge position is dynamic weight-bearing that was used in this study for the measurement of ankle dorsiflexion AROM as well as in the Robertson study.[19] This weight-bearing position is as same as in daily life during standing or walking, by which the extensibility of ankle muscles determine the ankle AROM. However, to minimize the measurement error during lunge position, the instructions and the same measurement protocol were strictly applied to all subjects.

Conclusion

From this study, we conclude that a 15-minute superficial heating application had an immediate effect on plantarflexor extensibility in healthy subjects. However, it is questionable whether the change in ankle dorsiflexion AROM of 2.96 degrees is clinically meaningful for individuals with restricted ROM or not. Therefore, a further study should focus on subjects with restricted ROM because we hypothesize that these subjects would be likely to show greater improvement than healthy subjects. A second research question for such a future study would be whether 15 or 30 minutes of superficial heating show better results for subjects with restricted ROM.

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