

Research article

Acute effects of two massage techniques on ankle joint flexibility and power of the plantar flexors

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Abstract

The purpose of this study was to determine if three minutes of petrissage and tapotement forms of massage would influence plantar flexors' flexibility, and muscle power. Nineteen participants were randomly subjected to three conditions (control and two massages) before performing two power tests. Prior to the intervention, subjects completed ankle joint flexibility assessments. The conditions were; (1) control, where subjects lay prone and had a therapist's hands resting, (2) vigorous petrissage, and (3) tapotement applied at a rate of 4Hz; all on the triceps surae. Following completion of the intervention, subjects immediately completed a post-ankle joint flexibility test, followed by a drop-jump and concentric calf raise. The power measures were; concentric peak force, rate of force development, and drop-jump height / contact time. The data showed a significant increase ($p < 0.05$) in ankle joint angle on the right leg and a corresponding tendency on the left. No significant change was seen with the power measures. Results suggest that massage can increase plantar flexors' flexibility without a change in power and thus may be an alternative to static stretching during an athletic warm-up.

Key words: petrissage, tapotement, warm-up, range of motion, jumps.

Introduction

The practice of massage has long been considered an integral part of sport preparation, conditioning and recovery (Cafarelli and Flint, 1993; Caldwell, 2001; Drust, et al., 2003; Harmer, 1991; Hemmings, 2001; Tiidus and Shoemaker, 1995). Since the time of ancient Greece, massage and sport have co-existed. However, it was not until the 1972 Munich Olympics where Lasse Viren attributed his two gold medals to a daily massage (Caldwell, 2001), that massage became synonymous with sporting achievement. In addition, more recently Callaghan (1993) and Clews (1999) reported extensive use of massage on their national Olympic teams.

Although massage is practised widely throughout sporting circles, the effects and mechanism associated with massage are unclear or anecdotal (Boone et al. 1991, Wiktorsson-Möller, et al., 1983; Cafarelli and Flint, 1993; Harmer, 1991; Hemmings, 2001; Tiidus and Shoemaker, 1995). Athletes use massage in an attempt to aid recovery as well as warm-up for training or competition (Boone et al., 1991; Cafarelli and Flint, 1993; Caldwell, 2001; Cash,

1996; Drust et al., 2003; Harmer, 1991; Hemmings, 2001; Tiidus and Shoemaker, 1995; Wiktorsson-Möller et al., 1983). Current recommendations from Sports Medicine Australia (2005) for warming-up prior to activity involve 2-3 minutes of jogging to raise a light sweat prior to stretching. This activity is to increase the heat throughout the body and reduce the risk of musculoskeletal injury by increasing tissue suppleness. Stretching follows to further reduce the risk of injury, reduce muscle tension and increase freedom of movement. However, there are numerous articles indicating that pre-event static stretching can impair force (Behm and Kibele, 2007; Behm et al., 2001; 2006), balance, reaction and movement time (Behm et al., 2004b) and jump landing contact time (Power et al., 2004). Although Nelson et al. (2001) found that the deleterious effect of prior stretching was limited to slower isokinetic velocities (60°/s and 120°/s), other studies have found prior static stretching to inhibit dynamic jump performance (Behm et al., 2006, Behm and Kibele, 2007; Young and Behm 2002,). Whereas increased ROM is coupled with performance impairments when static stretching is implemented, pre-event massage might improve ROM without the associated impairments. It would be important to discover if there are any massage-related impairments and if they could affect dynamic jump performance. While Hunter et al. (2006) reported that post-massage effects on isokinetic force were only significant at 60°/s; they also opined that the deleterious effect might only occur with the first contraction after massage. With the uncertainty in the literature it would be opportune to further investigate the effect of massage on jump measures.

Massage involves methodical pressure, friction and rubbing (Hemmings, 2001). Various strokes such as, effleurage, petrissage, tapotement and frictions have been developed from Swiss massage. Petrissage ("to knead") is a vigorous stroke, which compresses and releases soft tissue via picking up and squeezing the muscle and overlying tissues. It is aimed at stretching muscle fibres, increasing mobility between the tissue interfaces, aiding venous and lymph return, relaxing muscles, and in helping with the removal of wastes (Goats, 1994a; Paine, 2000). Tapotement is a percussive massage stroke, such as hacking, pecking or cupping; aimed at stimulating the cutaneous tissue and superficial muscle, aiding the preparation for competition (Goats, 1994b; Paine, 2000). Unfortunately, the factions that prescribe pre-event massage,

do not agree on the type, style, application, duration, intensity, number of strokes, or the time prior to competition required to benefit from massage (Caldwell, 2001; King, 1993; Paine, 2000). In addition, limited empirical data was found to substantiate each stroke's claimed benefit or if they had any effect at all. Therefore, both practitioner and recipient may have a poor understanding of the true nature of massage.

Currently, the majority of studies, on sports massage, focus on post-event conditions specifically aiding recovery from intense exercise and the relieving of delayed onset of muscular soreness symptoms (Weber et al., 1994). Very little research has been conducted on the pre-exercise or pre-event condition (Hemmings, 2001). Although various authors have speculated on the positive effects of massage (Cafarelli and Flint, 1993; Caldwell, 2001; Hemmings et al., 2000; Hemmings 2001; King, 1993; Paine, 2000), there is little scientific or empirical data to support these claims (Boone et al., 1991; Hemmings et al., 2000; Shoemaker et al., 1997). Furthermore, these studies have methodological problems. Duration of the treatment and the type and number of strokes conducted during the treatment are inconsistent, with these decisions often left up to the discretion of the therapist applying the treatment (Wiktorsson-Möller et al., 1983).

Consequently, scientific knowledge in the area of the pre-event massage is lacking. There is insufficient evidence to suggest that pre-event massage is of any physiological benefit, whether it has a positive or negative affect on performance and ROM. Hence, the purpose of the study was to establish whether particular massage strokes (petrissage or tapotement) had any effect on power performance of the plantar flexors and ankle joint flexibility immediately post-treatment.

Methods

Subjects

Nineteen students, who volunteered (8 female and 11 male) from the University of Ballarat, (mean; age = 21 ± 2.25 years, height = 1.78 ± 0.09 m, weight 76.59 ± 9.87 kg) participated in and completed the study. Following approval from the University Human Research and Ethics committee, all subjects read and signed an informed consent form prior to beginning the study. Subjects were required to be injury free in the ankles, lower legs and feet as well as have a moderate level of proficiency in jumping sports to decrease likelihood of injury from the test. Typically, this meant the subjects were participating in team sports such as Australian Rules football and netball at a recreational level.

Design

Subjects were required to attend four sessions throughout the study. All tests for each individual were conducted at approximately the same time of day to eliminate diurnal variations. The first session was a familiarisation / information session where the procedure and tests were described, demonstrated and practised. The remaining sessions were the test sessions, where the experiment was implemented. The order in which the test sessions were completed was randomly assigned (dice throw) prior to

commencement of the first test session. Each test session involved four components:

1. *Pre-intervention calf flexibility test where both ankles were tested for ROM.*
2. *Treatment / intervention which was either the control, massage treatment 1 (petrissage) or massage treatment 2 (tapotement), applied in a randomly assigned order.*
3. *Post intervention calf flexibility, where the subject completed the same ROM test, commencing on the same leg as in the pre-test.*
4. *Completion of two power jump tests conducted in random order.*

The above sequence was completed on three separate occasions, to allow the three different testing conditions to be conducted. All massage was completed in a laboratory free of other people or sounds to prevent external stimuli from influencing the result. The massage was performed on an Athlagen Access-lift electric table that was set at a height comfortable for the therapist to complete the massage. No adjustments of table height were permitted once a testing session commenced due to the noise associated with the motor. Testing bouts were conducted no closer than 48 hours and no further than 96 hours from each other. The control condition was conducted to account for possible influences of the resting prone position, oil or the contact of the hands on the skin. The same therapist was used for all subjects.

Familiarisation / information session

This session was conducted approximately one week prior to the commencement of testing. The purpose of this session was to inform the participant of the requirements of the study, familiarise each subject with the testing procedures, and demonstrate the massage styles to be performed.

Ankle joint flexibility measures

Ankle joint flexibility was assessed prior to and following the intervention. Subjects assumed a supine position with their hands above their heads on a wall to brace their body position for the measure to be performed. The hands were in this position to avoid sliding along the floor whilst the testers wound in the device. The machine was braced by one of the testers to avoid the machine from moving whilst the other tester wound the device. The testers also stabilised the subject's ankle firmly in the device to avoid any slippage of the foot in the machine (Figure 1).

The assignment of which leg would be tested first was determined randomly with an eight-sided die. The same order for the legs was used for pre- and post-testing. Once this order was determined, the subject was tested and received the treatment on this leg first for the duration of the study. Following this procedure, the plantar surface of the first foot was placed on the wooden plate of the ankle joint flexibility device. The plate was then wound slowly to increase ankle dorsiflexion. The subjects were to inform the testers when they reached a position that induced a sensation just prior to the onset of pain. The subject was instructed to look directly up at the ceiling to

avoid influence of visual stimulus in regards to ankle position. A reading was taken of the acute angle between the horizontal and movable plate on the degrees scale on the side of the device, with the measurement resolution 0.5 degrees. This angle was considered as the measure of passive flexibility of the plantar flexors. This procedure was then immediately repeated for the following leg. Only a single flexibility trial was conducted due to the time taken to perform the test. This test has been reliably used in previously published research (Young et al., 2006). Repeating this procedure could influence the subject's perception of the end point just before pain and consequently affect the overall result.



Figure 1. Ankle joint flexibility test.

Treatment interventions

The order in which each participant completed the interventions was predetermined randomly. The position for all three interventions was the same; lying prone on an Athlagen Access Lift electric table, with the feet hanging off the end of the table in a relaxed position. 'Cold-pressed' vegetable based oil was applied to each of the subjects over the plantar flexors. The amount of oil applied to each subject was sufficient to provide comfort during the vigorous application of petrissage without irritation of the skin or hair on the leg. No conversing between the therapist and subject was allowed, no noise, talking in the laboratory, music or anything else that could alter the mood state was permitted during the intervention.

Control condition

The control condition consisted of resting in a prone position as described above and the oil was applied. The massage therapist rested the hands on each leg over the triceps surae group for a period of three minutes on each leg. No movement of the therapist's hands was permitted throughout the duration of the application. Direct contact was used in the control to account for any influence of physical contact. This control was necessary due to the potential psychological effect of massage as demonstrated by Tyurin (1985).

Massage treatment 1 – Petrissage

The subject adopted a position as described above. The oil was applied to both legs as with the control. The therapist

then proceeded to massage the subject's plantar flexors with a vigorous kneading 'duck-billing' motion – petrissage (Figure 2). This was applied to one leg for a period of three minutes and then the other leg.



Figure 2. Petrissage massage technique.

Massage treatment 2 – Tapotement

The subject adopted the starting position as described above. Oil was applied as with the other two interventions, although not normally required for tapotement technique. This was done to be consistent with the preceding two interventions. A percussive hacking style (Figure 3) was applied to the plantar flexors for duration of three minutes each leg as per the other two interventions. The strike rate of this technique was vigorous at 4Hz. This was consistent throughout the total six minute time period. Consistency was ensured with the therapist wearing a "Walkman" with earphones and a compact disc playing a beeping noise every 0.5 s. The therapist was instructed to strike his right hand twice for each beat.

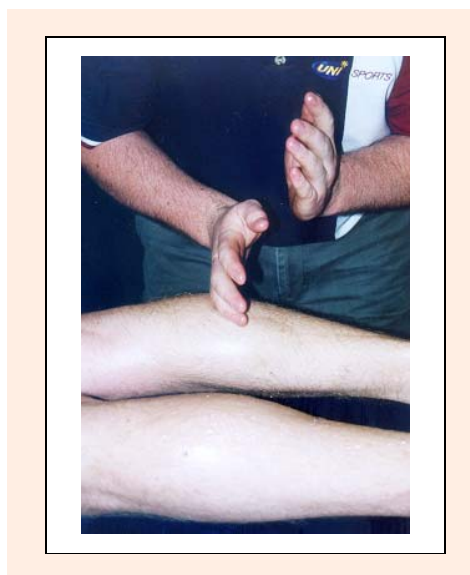


Figure 3. Tapotement massage technique.

To ensure consistency for all conditions, the same qualified massage therapist was used. The therapist had been practising massage professionally for over three years and was qualified with a Diploma of Health Science (Remedial Massage).

Jump procedures

All subjects on completing all other tests performed two tests of muscle power. The order, in which these tests were conducted, was randomly assigned. Once determined, the subject completed these tests in this order for the remainder of their test sessions. These two tests were selected as they are seen to be two differing neurophysiological methods of force generation (Young et al., 2006). The drop-jump involves a stretch-shortening cycle (SCC), whereas the concentric calf raise is a pure concentric contraction.

Drop jump

The drop jump was performed from a 30cm high box onto a contact mat system (Swift Performance Equipment) (Power et al., 2004; Young and Behm, 2002, Young and Elliott, 2001; Young et al., 2006). Subjects were instructed to keep their hands on their hips throughout the test, and to step off the box with a straight leg to ensure the fall began as close to 30cm as possible. The objective was to jump for maximum height and minimum contact time. As previous studies have indicated, these instructions produced short contact times (<200msec) and change the jumping task compared with jumping only for height (Power et al., 2004; Young and Behm, 2002; Young et al., 2006). The testers, to ensure correct technique and give feedback as required, repeated the cues of maximum height and minimum contact time. Each subject performed a maximum of two jumps with approximately 30 seconds rest between trials. The best score was retained for the final result.

The test yields two results, height achieved and contact time. The power measure is the height divided by contact time. As the flight time determines the height achieved, it is only valid if the subject lands in the exact position of the take-off. Consequently, the subjects' instructions were to land from their jumps with the hips and knees extended and the feet fully plantar flexed before flexing these joints to distribute the impact of landing. "Although this test does not totally isolate the plantar flexors, such a jumping technique has been shown to

reduce the activation of the quadriceps and increase the activation of the gastrocnemius compared to a drop jump for height only," (Young et al., 2006).

Concentric calf raise

This test was performed in a modified Smith Machine (Olympic bar is attached and guided along vertical rails) with a 10kg bar on the shoulders to enhance stability whilst performing the movement (Young et al., 2006). The subject was placed in the Smith Machine and instructed to remain still, on flat feet. Their weight was then measured and recorded. When instructed to 'go' the subject performed a maximal explosive concentric calf raise as 'hard and fast as possible'. Their knees had to remain locked throughout the test and their toes were to remain in contact with the ground. This test isolated the plantar flexors as hip and knee extension was eliminated. To decrease the subject utilising other muscles, their technique was assessed during the movement.

The power measures were captured with a Kistler force platform (Z4852/C) operating at 1000Hz. The software ascertained the absolute maximum force and reported this as peak force. The maximum rate of force development (RFD) was calculated as the greatest force increase over 5 msec on the ascending aspect of the curve. The subjects performed two trials, with the best score taken as the result. These parameters have been used previously (Young and Elliot, 2001).

Statistical analysis

To compare the measures of muscle power from the concentric calf raise and drop jump across these conditions, a one-way Analysis of Variance (ANOVA) with repeated measures was employed. For the flexibility measures, a two-way ANOVA, (3 conditions x 2 times {pre- and post-intervention}) with repeated measures, was also used; however, the focus was on the condition x time interaction since the flexibility results had a pre- and post-treatment score. The ANOVAs were conducted separately for right and left limbs. Significance was set at $p < 0.05$ for all tests. Effect sizes ($ES = \text{mean change} / \text{standard}$

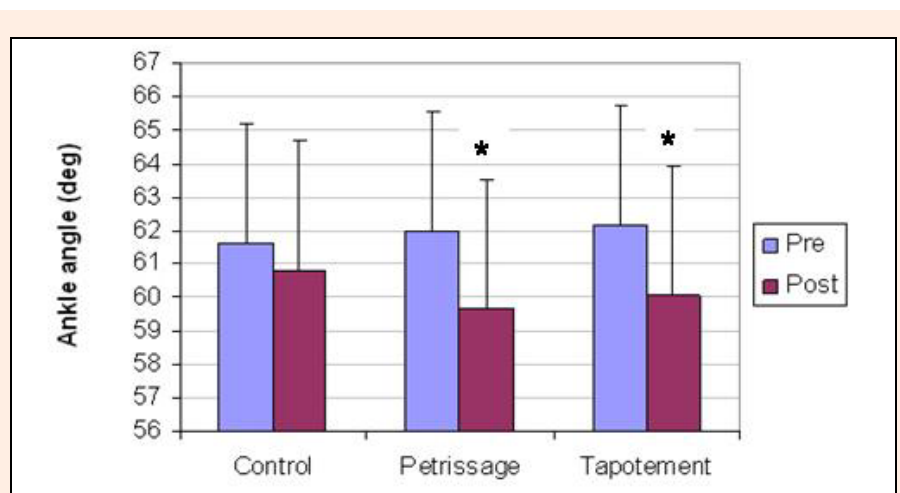


Figure 4. Mean ankle angle for the right leg. The symbol "*" represents that both post-massage measures experienced significantly ($p < 0.05$) greater change compared to the post-test control measure. A decreased angle signifies an increase in the range of motion (ROM). (Error bars represent the standard deviation [SD])

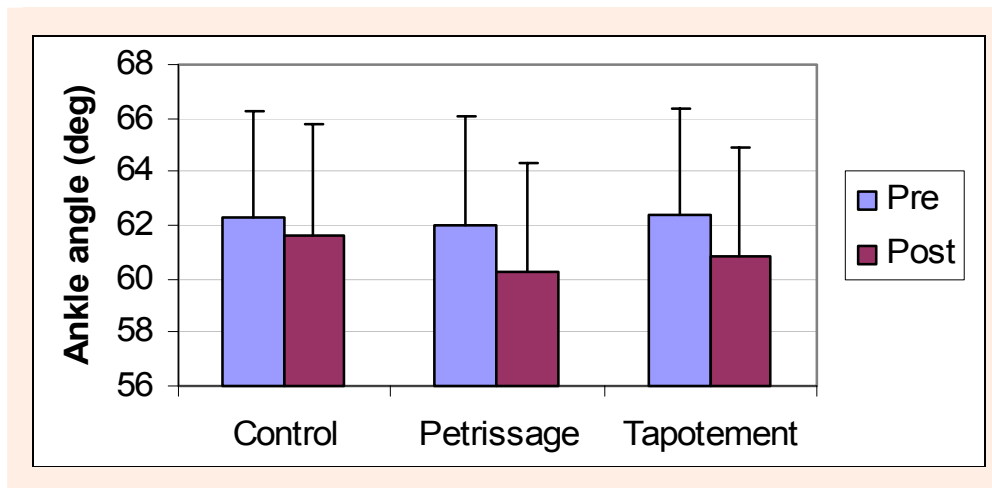


Figure 5. Mean ankle angle for the left leg. (Error bars represent the standard deviation [SD]).

deviation of the sample scores) were also calculated and reported (Cohen, 1988). Cohen applied qualitative descriptors for the effect sizes (ES) with ratios of less than 0.41, 0.41-0.70 and greater than 0.7 indicating small, moderate and large changes respectively.

Results

Ankle joint flexibility

There was a significant ($p < 0.01$) main effect for time (pre- vs. post-intervention) for both legs. For the right leg there was a significant group \times time interaction ($p < 0.05$) (Figure 4). To determine which condition was different, simple contrasts were performed revealing the gains in flexibility from pre- to post-massage were greater for the petrissage (3.7% ES = 0.64) and tapotement (3.2% ES = 0.62) compared to the control (1.3% ES = 0.18). There was no significant difference between either massage treatments for either leg.

For the left leg there was no statistical significance in ankle joint flexibility (Figure 5). Although not significant ($p = 0.34$), numerically, the two massage treatments had larger gains in flexibility compared with the control group (petrissage = 2.7% ES = 0.48: moderate, tapotement = 2.4% ES = 0.34: small, control = 1.1% ES = 0.1).

Power performance

There was no significant difference observed between the three conditions in any of the variables related to power (Table 1). The concentric calf raise also failed to yield any significant results.

Discussion

The purpose of this study was to determine if petrissage and tapotement forms of massage would influence the flexibility of the plantar flexors and muscle power.

Ankle joint flexibility

Unlike previous studies (Mikesky et al., 2002), this study was able to demonstrate a significant effect of massage on ROM. Interestingly, the ROM results showed significance only on the right and a corresponding numerical indication on the left reached a significance value of $p=0.34$. Effect size magnitudes (Cohen, 1988) indicated that both types of massage for the right ankle and petrissage for the left ankle caused moderate changes in ROM while tapotement had a small effect for the left ankle. However, when comparing the two massage techniques, the results were very similar. This was surprising, as it has been claimed that petrissage and tapotement have different effects on soft tissues and subsequently a greater difference between the two strokes may have been expected (Goats, 1994b). As discussed earlier, the proposed purpose of petrissage is to increase lymphatic and venous drainage, squeeze out metabolic waste products, promote deeper relaxation of tissues and stretch muscle fibres, making the tissue interface more mobile (Paine, 2000; Prentice, 2003). These claims would account for the increase in flexibility associated with petrissage via reducing stiffness at a fibre level and increasing muscle compliance. However, tapotement is claimed to increase muscle tone, vibrate tissues and stimulate cutaneous reflexes (Goats, 1994a). Its percussive nature works superficially stimulating muscles and cutaneous neural structures. Both techniques involved direct contact on the skin for a duration of three minutes. Throughout that time, a vigorous application of massage to the skin from either technique would stimulate the cutaneous receptors (Goats, 1994a). This application of rubbing or striking the skin for the prolonged period would overload the cutaneous receptors and possibly make recognising the end point of the stretch more difficult. This hypothesis is in agreement with Magnusson et al. (1996) who attributed increases in ROM more to increases in stretch tolerance than to changes in tissue compliance or stiffness.

Table 1. Mean data (standard deviations) for power tests.

	Control	Petrissage	Tapotement
Drop Jump: Contact time / height ($\text{cm}\cdot\text{s}^{-1}$)	132.8 (33.5)	138.2 (31.4)	137.5 (31.2)
Concentric Calf Peak Force (body weight)	.96 (.18)	.96 (.19)	.97 (.18)
Rate of force development ($\text{N}\cdot\text{s}^{-1}$)	11124 (376)	11098 (402)	11063 (362)

As there was no significant difference between the two massage styles, the style of massage may not be significant in regards to improving the flexibility. Perhaps the act of vigorous skin contact, regardless of the action performed, would have the same effect.

Power performance

When comparing the effects of massage on the power of the plantar flexors no significant change was noted for either the drop-jump or the concentric calf raise. Similarly, Mikesky et al. (2002) used a jump test when assessing massage and vertical jump power. Again, their study failed to yield any significant results with the counter movement jump. The lack of impairment in jump performance following the massage techniques is in contrast to studies examining the effect of static stretching. A number of studies have illustrated that prior to activity; static stretching can impair force (Behm and Kibele, 2007, Behm et al., 2001; 2006), jump performance (Cornwell et al., 2002; Young and Elliot, 2001; Young and Behm, 2002), balance, reaction and movement time (Behm et al., 2004b) and jump landing contact time (Power et al., 2004). Young et al. (2006) showed that increasing the stretch duration increased the decrement in the drop jump performance. Consequently, if massage can increase muscle length without affecting performance in power events it could be hypothesised that vigorous, short duration massage may be a better method of preparing the body just prior to a power event compared with static stretching. However, to further emphasize the point, massage in this study did not positively affect power performance, it just did not impair performance.

Ankle joint flexibility and power

Stretch-induced decrements in force and power have been attributed to an increase in compliance (Fowles et al., 2000; Taylor et al., 1990) and an inhibition of muscle activation (Avela et al., 1999; Behm et al., 2001; Fowles et al., 2000). The increased ankle joint flexibility of this study might also be attributed to an increased muscle compliance, which in turn would potentially adversely affect the plantar flexors' force length relationship. However, there were no significant changes in power with the massage conditions.

An increase in ankle joint flexibility may occur due to an increase in muscle temperature altering tissue viscosity and tissue compliance. Drust et al. (2003) demonstrated significant increases in muscle temperature, up to a depth of 2.5cm with massage application. However this is not as encompassing as an active warm-up that involves muscular contractions. Numerous static stretching studies use an active warm-up followed by a stretch to the 'point of discomfort' (Behm and Kibele, 2007, Behm et al., 2001; 2004a; 2006; Power et al., 2004, Young and Behm, 2002). As a consequence, a decrease in muscle viscosity and increase in compliance should result. However according to the previously cited studies, an increase in muscle compliance should result in a decrease in power. Perhaps the hypothetical positive effects of massage on the neural system counterbalance or eliminate the negative effect of increased compliance.

Furthermore, massage is performed within a subject's tolerance levels. The verbal cue of 'point of discomfort', as described in static stretching studies, may not be achieved keeping the muscle below the elastic limit. Alter (1996) defined the elastic limit as the smallest value of stress required to produce a permanent strain on the body. He states that increasing the stress beyond this point would result in a stressed connective tissue and muscle and as a result these tissues would not return to their original length. Consequently, static stretching to the 'point of discomfort' may exceed the elastic limit altering the ability to generate power, whereas massage might not reach this level and not affect the tissue in this manner.

Conclusion

The results of this investigation indicate a moderate magnitude of effect in ankle joint flexibility following the application of either three minutes of petrissage or tapotement (only to the right ankle) massage to the plantar flexors. In addition, there was no significant change in the power measures following either of the massage treatments. Consequently, with no decrement in power and a moderate increase in ankle joint flexibility, massage presents an alternative method to static stretching to increase ROM in a warm up. Despite the varying claimed effects of the two different massage techniques there was no significant difference.

References

- Alter, M.J. (1996) *Science of flexibility*. Human Kinetics Publ. Windsor Ontario, Canada. Chapter 5. 59-83.
- Avela, J., Kyrolainen, H. and Komi, P. (1999) Altered reflex sensitivity after repeated and prolonged passive muscle stretching. *Journal of Applied Physiology* **86**, 1283-1291.
- Behm, D., Carrol, M. and Button, D. (2004a) The effect of an acute bout of submaximal intensity stretching on hamstring force, activation and rate of force development. *Canadian Journal Applied Physiology* **29(Suppl)**, S39.
- Behm, D., Button, D. and Butt, J. (2001) Factors affecting force loss with prolonged stretching. *Canadian Journal of Applied Physiology* **26**, 261-272.
- Behm, D.G. and Kibele, A. (2007) Effects of differing intensities of static stretching on jump performance. *European Journal of Applied Physiology*, in press.
- Behm, D., Bambury, A., Cahill, F. and Power, K. (2004b) The Effect of Acute static stretching on force, balance, reaction time and movement time. *Medicine and Science in Sports and Exercise* **36(8)**, 1397-1402.
- Behm, D.G., Bradbury, E.E., Haynes, A.T., Hodder, J.N., Leonard, A.M. and Paddock, N.R. (2006) Flexibility is not related to stretch-induced deficits in force or power. *Journal of Sports Science and Medicine* **5**, 33-42.
- Boone, T., Cooper, R. and Thompson, W.A. (1991) Physiologic Evaluation of the Sports massage. *Journal of the National Athletic Therapy Association* **26**, 51-54.
- Cafarelli, E. and Flint, F. (1993) The role of massage in preparation for and recovery from exercise. *Physiotherapy in Sport* **16**, 17-20.
- Caldwell, E. (2001) *Remedial massage therapy*. Corpus Publishing Ltd. Fishbourne, Chichester. 35-41.
- Callaghan, M. (1993) The role of massage in the management of the athlete: a review. *British Journal Sports Medicine* **27**, 28-33.
- Cash, M. (1996) *Sports & remedial massage therapy*. Butler and Tanner Ltd. Frome, Somerset. Chapter 8. 58-65.
- Clews, W. (1999) Massage Why? *Women in sport (Melbourne, Aust.)* **5(3)**, 10-11.
- Cohen J. (1988) *Statistical power analysis for the behavioral sciences*. 2nd Edition. Hillsdale NJ, L. Erlbaum Associates Publishing.

- Cornwell, A., Nelson, A. and Sidaway, B. (2002) Acute effects of stretching on the neuromechanical properties of the triceps surae muscle complex. *European Journal of Applied Physiology* **86**, 428-434.
- Drews, T., Kreider, R., Drinkard, B., Cortes, C., Lester, C., Somma, C., Shall, L. and Woodhouse, M. (1990) Effects of post-event massage on repeated ultraendurance cycling. *International Journal Sports Medicine* **11**, 407.
- Drust, B., Atkinson, G., Gregson, W., French, D. and Binningsley, D. (2003) The effects of massage on the intramuscular temperature in the vastus lateralis in humans. *International Journal Sports Medicine* **24**, 395-399.
- Fowles, J. and Sale, D. (1997) Time course of strength deficit after maximal passive stretch in humans. *Medicine and Science in Sports and Exercise* **29**, S26.
- Fowles, J., Sale, D., MacDougall, J. (2000) Reduced strength after passive stretch of the human plantar flexors. *Journal Applied Physiology* **89**:1179-1188.
- Goats, G. (1994a) Massage – the scientific basis of an ancient art: part 1. *British Journal of Sports Medicine* **28(3)**, 149-152.
- Goats, G. (1994b) Massage – the scientific basis of an ancient art: part 2. *British Journal of Sports Medicine* **28(3)**, 153-156.
- Harmer, P. (1991) The effect of pre-performance massage on stride frequency in sprinters. *Journal of the National Athletic Therapy Association* **26**, 55-59.
- Hemmings, B. (2001) Physiological, psychological and performance effects of massage therapy in sport: a review of literature. *Physical Therapy in Sport* **2**, 165-170.
- Hemmings, B. (2000) Psychological and immunological effects of massage after sport. *British Journal of Therapy and Rehabilitation* **7(12)**, 516-519.
- Hemmings, B. (2000) Sports massage and psychological regeneration. *British Journal of Therapy and Rehabilitation* **7(4)**, 184-189.
- Hemmings, B., Smith, M., Graydon, J. and Dyson, R. (2000) Effects of massage on physiological restoration, perceived recovery, and repeated sports performance. *British Journal Sports Medicine* **34**, 109-115.
- Hunter, A. M., Watt, J.M., Watt, V. And Galloway, S.D. (2006) Effect of lower limb massage on electromyography and force production of the knee extensors. *British Journal of Sports Medicine* **40(2)**, 114-118.
- King, R. (1993) *Performance massage*. Human Kinetics Publishers, Champaign, Illinois. 8-72.
- Magnusson, S.P., Simonsen, E.B., Aagaard, P., Sorensen, H. and Kjaer, M. (1996) A mechanism for altered flexibility in human skeletal muscle. *Journal of Physiology* **497(1)**, 291-298.
- Mikesky, A., Bahamonde, R., Stanton, K., Alvey, T. and Fitton, T. (2002) Acute effects of the stick on strength, power and flexibility. *Journal of Strength and Conditioning Research* **16(3)**, 446-450.
- Nelson, A.G., Guillory, I.K., Cornwell, A. and Kokkonen, J. (2001) Inhibition of maximal voluntary isokinetic torque production following stretching is velocity-specific. *Journal of Strength and Conditioning Research* **15(2)**, 241-246.
- Paine, T. (2000) *The complete guide to sports massage*. A & C Black Publishing Ltd. London. Chapter 9. 79-114.
- Power, K., Behm, D., Cahill, F., Carroll, M. and Young W. (2004) An acute bout of static stretching: Effects on force and jumping performance. *Medicine and Science in Sports and Exercise* **36(8)**, 1389-1396.
- Prentice, W. (2003) *Therapeutic Modalities*, 5th Edition. Mosby, St Louis. 431-522.
- Shoemaker, J., Tiidus, P. and Mader, R. (1997) Failure of manual massage to alter limb blood flow: measure by Doppler ultrasound. *Medicine and Science in Sports and Exercise* **29**, 610-614.
- Sports Medicine Australia (SMA). (2005) Recommendations for Warm-Up – Stretching. Available from URL: <http://www.sma.org.au>
- Taylor, D., Dalton, J., Seaber, A. and Garrett, W. (1990) Viscoelastic properties of muscle-tendon units. The biomechanical effects of stretching. *American Journal Sports Medicine* **18**, 300-309.
- Tiidus, P. and Shoemaker, J. (1995) Effleurage massage, muscle blood flow and long-term post-exercise strength recovery. *International Journal of Sports Medicine* **16**, 478-483.
- Tiidus, P. (1997) Manual massage and recovery of muscle function following exercise: a literature review. *Journal Orthopaedic and Sport Physical Therapy* **25(2)**, 107-112.
- Tyurin, A. (1985) The influence of different forms of massage on the psycho-emotional state of athletes. *Teoriya I Praktika Fizicheskoi Kultury* **7**, 19-20.
- Weber, M., Servedio, F. and Woodall, W. (1994) The effects of three modalities on delayed onset of muscular soreness. *Journal Orthopaedic and Sport Physical Therapy* **20(5)**, 236-242.
- Wiktorsson-Möller, M., Öberg, B., Ekstrand, J. and Gillquist, J. (1983) Effects of warming up, massage, and stretching on range of motion and muscle strength in the lower extremity. *American Journal Sports Medicine* **11(4)**, 249-252.
- Young, W. and Behm, D. (2002) Effect of running, static stretching and practice jumps on explosive force production and jumping performance. *Journal of Sports Medicine and Physical Fitness* **42**, 1-99.
- Young, W. and Elliott, S. (2001) Acute effects of static stretching, proprioceptive neuromuscular facilitation stretching, and maximal voluntary contractions on explosive force production and jumping performance. *Research Quarterly for Exercise and Sport* **72**, 273-279.
- Young, W., Elias, G. and Power, J. (2006) Effects of static stretching volume and intensity on plantar flexor explosive force production and range of motion. *Journal of Sports Medicine and Physical Fitness* **46(3)**, 403-411.

Key points

- Three minutes of petrissage and tapotement forms of massage increased ankle flexibility.
- Massage did not adversely affect jump power measures.
- Massage may be an effective alternative to static stretching as a component of a pre-event warm-up.

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