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Research

Massage therapy slightly decreased pain intensity after habitual running, but had no effect on fatigue, mood or physical performance: a randomised trial

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KEY WORDS

Musculoskeletal manipulations
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ABSTRACT

Question: Does massage therapy reduce pain and perceived fatigue in the quadriceps, and improve the mood and physical performance of runners after habitual sporting activity (10-km run)? **Design**: Randomised controlled trial with concealed allocation, intention-to-treat analysis and blinded assessment. **Participants**: Seventy-eight runners after sporting activity (10-km run). **Intervention**: The experimental group received 10 minutes of massage to the quadriceps aimed at recovery following sport practice, and the control group received a sham joint mobilisation. **Outcome measures**: Pain and perceived fatigue were each assessed using a 0-to-10 numerical rating scale; pain behaviour via the McGill Pain Questionnaire; mood profile via Brunel Mood Scale; quadriceps muscle flexibility using maximal knee flexion angle via inclinometer; isometric muscle strength of knee extensors via hand-held dynamometry; and vertical jump performance using jump height via My Jump 2 app. Evaluations were carried out immediately before and after the intervention, and at 24, 48 and 72 hours after the intervention. Generalised estimating equations were used to estimate a between-group difference (95% CI) using data across all time points. **Results**: The experimental group had significantly lower scores than the control group on the numerical rating scale for pain by 0.7 points (95% CI 0.1 to 1.3). There were no significant between-group differences for any of the other outcome measures. **Conclusion**: Massage therapy was effective at reducing pain intensity after application to the quadriceps of runners compared to a sham technique, but the magnitude of the effect was small. There were no significant effects on perceived fatigue, flexibility, strength or jump performance. **Trial registration**: Brazilian Registry of Clinical Trials, RBR-393m7m. **[Bender PU, Luz CM, Feldkircher JM, Nunes GS (2019) Massage therapy slightly decreased pain intensity after habitual running, but had no effect on fatigue, mood or physical performance: a randomised trial. *Journal of Physiotherapy* 65:75–80]**

Introduction

Massage therapy is widely used to treat patients with different conditions.[1] Reports have suggested that massage therapy acts by: blocking noxious stimuli, in line with the gate-control theory;[2] increasing blood and lymphatic flow, which may accelerate the elimination of catabolites;[3] and releasing endorphins that promote a feeling of well-being.[4]

In sports, massage therapy is often used in physical recovery after activities, to promote pain relief and prevent delayed-onset muscle soreness (DOMS).[4,5] A previous study reported that massage therapy reduced acute pain and fatigue in the quadriceps of triathletes after a long-distance Ironman race.[6] Some research has also suggested that massage therapy may decrease DOMS.[7,8] Imtiyaz et al found that massage therapy applied before the induction of fatigue in the arms may reduce DOMS in healthy non-athletic females.[8] Although massage therapy may be beneficial to athlete recovery, its use in clinical practice for sports is not supported by strong evidence.[5,9]

Most studies investigating the effects of massage therapy on athlete recovery have applied the intervention in cases of extreme fatigue, which does not reflect the typical state of many participants in many sports.[6,7,10,11] In clinical practice, clinicians use massage therapy to assist athletes to recover from less fatiguing sports such as competitive running and soccer. To date, no study has evaluated the effects of massage therapy on athlete recovery after sporting activity that does not induce extreme fatigue and may not cause DOMS.

Engaging in very strenuous sport can negatively affect the mood and performance of athletes[12,13] and, according to massage effect theories, massage therapy may also ameliorate these effects.[14,15] Arroyo-Morales et al[14] applied massage therapy after strenuous physical activity and found that massage therapy may improve perceived vigour using a mood questionnaire in healthy active students. Kargarfard et al[15] reported that massage therapy applied to the quadriceps of bodybuilders after fatiguing activity may enhance vertical jump performance. However, methodological issues related

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to sample size[10,16] or blinding[14,15] have been identified in previous studies investigating the impact of massage therapy on mood and physical performance. Additionally, the effects of massage therapy on these aspects after less fatiguing sports are yet to be studied.

Some research indicates that massage therapy is a useful technique in athlete recovery;[6,9–11] however, the short-term and long-term effects of massage therapy are still unclear.[5,9] Additionally, little is known about the effect of massage therapy applied after habitual sporting activity because no study has used methods that incorporate a real, habitual, sporting activity as the intervention.

Therefore, the research question for this randomised controlled trial was:

> Does massage therapy reduce pain and perceived fatigue in the quadriceps and improve the mood and physical performance of runners after habitual sporting activity (10-km run)?

Method

Design

This was a randomised clinical trial in which the participants were allocated to an experimental group or a control group. The experimental group received massage therapy to the quadriceps muscle aimed at recovery after sporting activity, and the control group received sham hip and knee joint mobilisations. The randomisation was conducted using sealed and opaque envelopes to conceal each upcoming allocation during recruitment. A researcher who was not involved in the evaluations or interventions of this study prepared these envelopes. The study design is presented in Figure 1.

Participants, therapists, centres

Seventy-eight runners from the metropolitan area of a state capital in Brazil took part in this study. To be eligible for inclusion in the study, athletes had to run a minimum of 10 km continuously and be aged between 18 and 60 years. They also had to have engaged in running practice for at least 1 year prior to data collection and be training at least twice per week. The exclusion criteria were the presence of any medical condition not compatible with the study procedures, severe metabolic or cardiorespiratory disorders, musculoskeletal disorders in the lower limbs in the last 6 months, abrasions in the thigh, cramps during evaluations and/or any sensation change in the thigh.

The evaluations and interventions were carried out at the participants' training sites. First, the participants were assessed in terms of the eligibility criteria and data were collected about their anthropometric characteristics. Next, the participants were instructed to run 10 km as fast as possible, reproducing their competition pace. Immediately after the run, the first evaluation session was carried out (pre-intervention) and the participants were evaluated for pain, fatigue, mood and physical performance. The measurements were taken in relation to the most painful quadriceps muscle, as reported using a numerical rating scale. If participants reported the same pain level in both thighs or no pain, the side to be evaluated and treated was randomly selected by a coin toss.

In order to maintain assessor blinding, after the pre-intervention assessment the participants were directed to a different location for

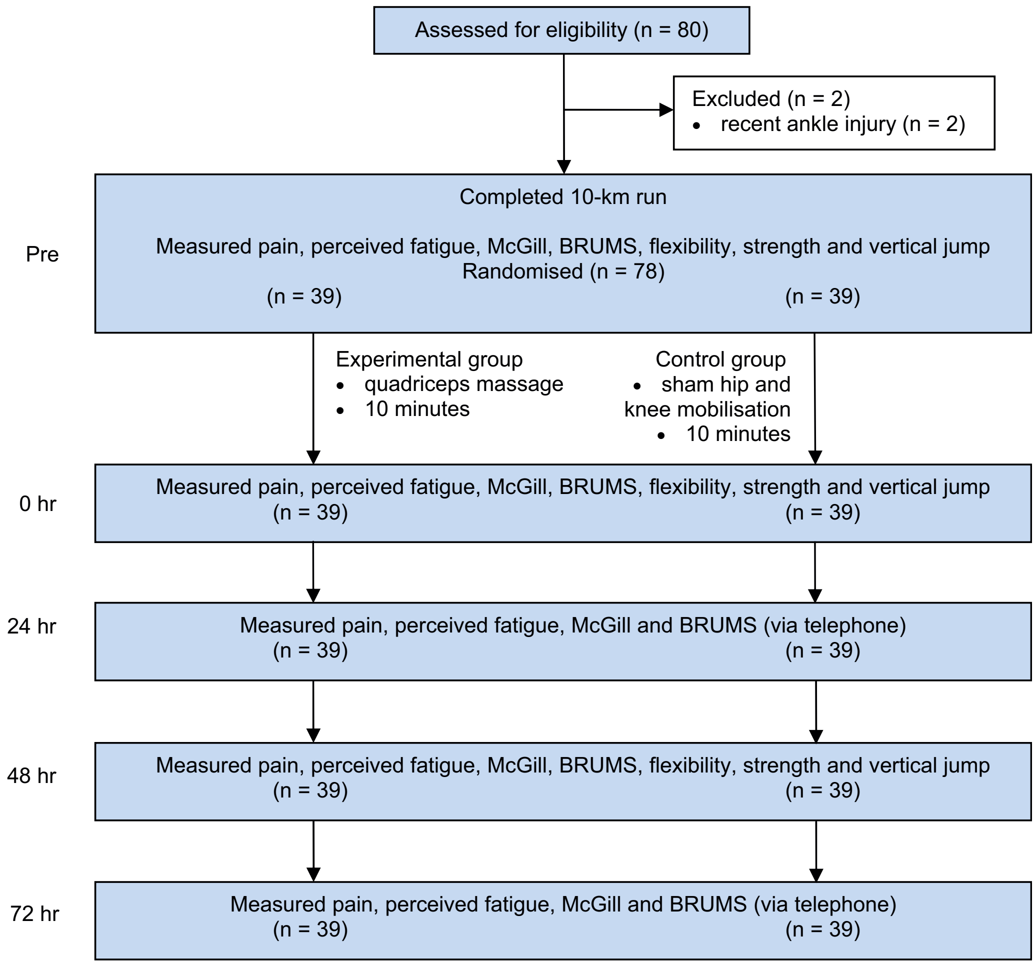

Figure 1. Design and flow of participants through the study.
BRUMS = Brunel Mood Scale, McGill = McGill Pain Questionnaire.

group allocation and the application of interventions. The same blinded assessor revaluated the participants immediately after the interventions (post-intervention), as well as at 24 hours, 48 hours and 72 hours after the intervention (Figure 1). The evaluations at 24 hours and 72 hours were conducted by telephone, to determine pain, fatigue and mood. At the immediate post-intervention assessment, the participants were instructed not to take anti-inflammatory or analgesic medications and not to perform other physical recovery techniques or additional physical activities during the data collection period. The participants were also given a leaflet containing the instructions and the questions that would be asked during the telephone calls.

Intervention

After the run, the experimental group received a 10-minute massage, aimed at physical and mood recovery,[5] from a therapist who was not involved in the measurements. Further detail is provided in Appendix 1, part A (see eAddenda for Appendix 1). The intervention consisted of the following procedures: 1 minute of superficial effleurage, in which the therapist slid both hands in the direction of the muscle fibres from distal to proximal with a gentle pressure on the thigh; 3 minutes of deep effleurage, in which the therapist performed the same movement but applied more pressure to the thigh; 3 minutes of petrissage, in which the therapist used the entire surface of the palm of the hands to compress and lift the tissue sequentially; 1 minute of tapotement, in which the therapist agitated the tissues of the thigh with cupped hands; and 2 minutes of superficial effleurage to finish the intervention. A video demonstration of the techniques is presented in Appendix 2 (see eAddenda for Appendix 2). Hypoallergenic skin oil was used to reduce friction between the therapist's hands and the participant's skin.

The control group received sham hip and knee joint mobilisations from the same therapist. Further detail is provided in Appendix 1, part B (see eAddenda for Appendix 1). The mobilisations served no therapeutic purpose and were applied only to promote a feeling of slight pressure on the skin without proper joint mobilisation. The participants were in supine with the knee flexed at 90 deg. For sham hip joint mobilisation, a belt was placed on the participant's inguinal region and around the therapist's lumbar region. For sham knee joint mobilisation, a belt was placed around the proximal region of the participant's tibia and around the therapist's lumbar region. From these positions, the therapist projected his/her body in order to move away from the participants, producing a slight and oscillatory pressure on the skin for 5 minutes in each mobilisation (images of the sham techniques are presented in Appendix 3 (see eAddenda for Appendix 3). At the end of the sham mobilisations, the same oil used in the experimental group was applied to the participants' leg in order to keep the assessor blinded to group allocation.

Outcome measures

Pain and perceived fatigue

The pain and perceived local fatigue in the quadriceps muscle were each measured using a numerical rating scale.[17,18] The scale consisted of a numerical sequence between 0 and 10 points, in which 0 indicated no pain or fatigue and 10 points indicated the worst possible pain or extreme fatigue. This numerical rating scale has adequate reliability for pain assessments (ICC = 0.91)[17] and is responsive to fatigue changes.[18]

Pain behaviour

The intensity and behaviour of pain were evaluated using the short form of the McGill Pain Questionnaire.[19] The questionnaire includes 15 pain descriptors, which describe different pain characteristics. Each descriptor is ranked on a 4-point rating scale between 0 and 3 points, in which 0 indicates 'none' and 3 indicates 'severe'. The total score is given by the sum of the points and varies between 0 and 45; high scores mean worse pain sensation.[19]

Mood profile

Mood was evaluated using the Brunel Mood Scale.[20] The scale includes 24 descriptors divided in six subscales: fatigue, tension, vigour, mental confusion, depression and anger. Each descriptor is ranked according to the question 'How do you feel now?' on a 5-point rating scale between 0 and 4 points, in which 0 indicates 'none' and 4 indicates 'extremely'. The total score of each subscale is given by the sum of the points and varies between 0 and 16; high scores mean greater presence of the respective mood parameter.[20]

Flexibility

Quadriceps flexibility was evaluated using the maximal knee flexion angle.[21] The participant lay prone with the hips in a neutral position. The assessor passively flexed the participant's knee until end feel was perceived or the participant's pelvis began to move. The knee flexion angle was measured once using an inclinometer[a] positioned 15 cm distal to the tibial tuberosity. This measure has adequate reliability (ICC = 0.94).[21]

Vertical jump performance

Jump height was evaluated using a mobile phone app[b].[22] The participants were instructed to perform a countermovement jump as high as possible, with arm swings permitted, and were recorded using a mobile phone[c]. Three jumps were performed, with a minimum 30-second interval between trials and the highest trial was used in statistical analysis.[23] The app was validated and has adequate reliability (ICC = 0.99).[22]

Isometric strength

Maximum knee extensor isometric strength was assessed using a hand-held dynamometer[d]. The participants were lying in supine position with hips and knees flexed at approximately 60 deg. An image of the strength assessment is presented in Appendix 4 (see eAddenda for Appendix 4). An inelastic strap was positioned around their ankles and the examination table, and the dynamometer was placed between the strap and the ankle of the assessed lower limb.[21] The participants were verbally encouraged to generate maximal effort against the strap as if extending their knee. One trial was performed before data collection for familiarisation purposes. Three 5-second trials were performed, with a minimum 30-second interval between each trial. Maximal isometric force was converted into torque: force in Newtons x leg length in metres (distance between the lateral femoral epicondyle and the lateral malleolus); and then, torque was normalised by body mass in kg ([Nm/kg]*100 = % body mass).[21] This procedure has adequate reliability (ICC = 0.98).[21]

Data analysis

Sample size was calculated to allow for statistical power of 80%, an alpha of 5% and potential loss to follow-up of 5%. This indicated that at least 38 participants would be necessary to identify a between-group difference in pain of 2 points (SD = 3 points)[7] and in fatigue of 1 point (SD = 1.5 points),[10] using the numerical rating scale. The calculation was performed using the software G*Power[e].

The intention-to-treat approach was adopted in all analyses. Five participants were not assessed on knee extensor strength and the missing data were processed using the multiple imputation method.[24] Twenty imputed data sets were created using the anthropometric and strength data from all the assessments to predict the missing data; the imputed data sets were pooled into mean values for analysis.[24,25]

The differences from baseline were used in the analysis. Analysis of variance with a linear mixed model was used to compare the effect of massage therapy between the experimental and control groups. Mean difference and 95% CI were also calculated for each comparison. The effect of the intervention on the primary outcome was estimated using generalised estimating equation with a linear mixed model that incorporated data from all the assessment time points into a single result.[26] The secondary outcomes underwent a similar analysis based on the available assessment time points. The analyses were adjusted

Table 1
Characteristics of participants.

Characteristic	Exp (n = 39)	Con (n = 39)
Age *(yr)*, mean (SD)	34 (9)	34 (10)
Gender, males:females	23:16	28:11
Height *(m)*, mean (SD)	1.72 (0.08)	1.74 (0.09)
Weight *(kg)*, mean (SD)	70.8 (11.2)	74.2 (11.8)
Time to complete 10-km run on the day of data collection *(minutes)*, mean (SD)	56.7 (8.3)	54.7 (8.2)
Running experience *(yr)*, mean (SD)	5.3 (4.8)	5.4 (5.3)

Exp = experimental group, Con = control group.

for baseline values as a covariate. A significance level of $p \le 0.05$ was adopted and the statistical analysis was performed using the software SPSS[f].

Results

Flow of participants, therapists, centres through the study

All participants (n = 78) completed the planned evaluations between March and September 2018 (Figure 1). Two participants in the experimental group and three participants in the control group did not have their muscle strength evaluated due to equipment failure. The groups were similar with respect to anthropometric data, running experience and 10-km running performance (Table 1), as well as baseline score on the outcome measures (first two columns of Table 2).

Compliance with the study protocol

No ineligible participants were randomised. No assessors were unblinded during the study. All participants received the designated intervention and were analysed in the group to which they had been randomly allocated.

Effect of the massage intervention

Means and standard deviations for all the measures at each assessment time point are shown in Table 2. Individual participant data are presented in Table 3 (see eAddenda for Table 3). A significant between-group difference was identified for pain assessed using the 0-to-10-point numerical rating scale (Table 2). The generalised estimating equation indicated that the overall between-group difference due to the massage therapy was 0.7 points lower pain intensity (95% CI 0.1 to 1.3).

No significant between-group differences were identified for fatigue, pain behaviour, mood profile or physical performance (Table 2).

Discussion

This study aimed to evaluate the impact of massage therapy on athlete recovery after habitual sporting activity. The results indicate that massage therapy reduced pain severity compared to a sham technique, but no statistically significant effects were identified on any of the other outcome measures. These results appear to be believable because the study used robust methods (true randomisation, concealed allocation, assessor blinding, intention-to-treat analysis, follow-up of all participants, and a low risk of type-I error).

Several factors suggest that the effect on pain intensity is not clinically worthwhile. The estimate of the effect on pain and the 95% CI around that estimate were below the effect of 2 points on the 0-to-10 scale, which was nominated as the smallest worthwhile effect in the sample size calculation. The McGill Pain Questionnaire did not show corresponding improvements in overall pain behaviour. Perhaps most importantly – from the perspective of athlete recovery, at least – the effect on pain was not enough to permit improvements in knee extensor strength, quadriceps flexibility or jump height.

Although the effect on pain severity does not appear to be clinically worthwhile, it is interesting to consider the pattern of the effect and the possible mechanisms behind this analgesic effect. Inspection of the data in Table 2 shows that the largest effect occurred immediately after the intervention was applied. This acute pain reduction may be due to the possible action of massage therapy on neurological aspects.[2,9,27] The mechanical stimuli from massage therapy may inhibit pain by 'closing the pain gate', inducing instant analgesia (gate-control theory).[2,9,27] Another potential explanation for the acute effect of massage therapy on pain is its impact on physiological aspects.[9,28,29] The stimuli from massage therapy may cause an immediate feeling of relaxation and consequent analgesia, due to the realise of β-endorphins[9,28,29] and/or a decline in the level of stress hormones.[29] Massage therapy may also influence psychological aspects,[30] although no effect on mood parameters was observed in the present study. Perhaps the instrument used (the Brunel Mood Scale) is not sensitive enough to detect the influence of an immediate feeling of well-being on the mood parameters, making this a possible reason for our results. It is important to underscore that the explanations for massage therapy effects are based on theories, and no biochemical or neurophysiologic analyses were performed in this study to investigate the mechanisms of massage therapy effects. Nonetheless, the acute effect of massage therapy on pain identified here corroborates previous research and demonstrates its effectiveness in acute pain relief in athletes.[6,7,11]

The acute analgesic effect showed some persistence through the later assessment time points and then disappeared by 72 hours. The impact of massage therapy on delayed pain could occur via physiological mechanisms.[9,31,32] It is suggested that DOMS is caused by the increased production and accumulation of free radicals after

Table 2
Mean (SD) of groups, and between-group difference estimated across available assessment time points using a generalised estimating equation (95% CI).

Outcomes	Pre		Post		24 h		48 h		72 h		Between-group difference (95%)
	Exp	Con	Exp	Con	Exp	Con	Exp	Con	Exp	Con	Exp – Con
Pain *(0 to 10)*, mean (SD)	1.2 (1.6)	0.7 (1.2)	0.2 (0.6)	0.5 (1.3)	0.8 (1.5)	1.0 (1.7)	0.4 (1.3)	0.5 (0.9)	0.2 (0.7)	0.1 (0.3)	–0.7 (–1.3 to –0.1)
Perceived fatigue *(0 to 10)*, mean (SD)	3.2 (2.3)	2.6 (2.4)	0.8 (1.2)	0.5 (1.1)	1.1 (1.9)	1.2 (1.6)	0.5 (1.4)	0.4 (0.8)	0.2 (0.7)	0.2 (0.4)	–0.1 (–0.3 to 0.2)
McGill Pain Questionnaire *(0 to 45)*, mean (SD)	3.3 (2.9)	3.5 (2.9)	1.0 (1.2)	1.2 (1.9)	1.7 (2.2)	2.2 (2.2)	1.0 (2.6)	1.0 (1.7)	0.5 (1.2)	0.5 (1.1)	–0.1 (–0.6 to 0.4)
BRUMS fatigue *(0 to 16)*, mean (SD)	4.2 (3.3)	3.9 (3.6)	1.8 (1.9)	2.1 (2.3)	2.2 (3.2)	2.2 (2.3)	1.2 (1.7)	1.9 (2.5)	1.5 (2.1)	1.1 (1.9)	–0.2 (–0.9 to 0.5)
BRUMS tension *(0 to 16)*, mean (SD)	1.0 (2.3)	1.3 (1.9)	0.4 (1.2)	0.8 (1.2)	0.9 (1.8)	1.7 (1.9)	1.0 (2.3)	1.1 (1.5)	0.9 (2.2)	1.5 (1.9)	–0.3 (–1.0 to 0.3)
BRUMS vigour *(0 to 16)*, mean (SD)	10.3 (3.6)	10.5 (3.3)	10.0 (3.6)	10.2 (3.5)	9.1 (3.5)	9.6 (3.7)	9.2 (4.0)	10.0 (3.9)	10.0 (4.0)	10.8 (3.8)	–0.5 (–1.7 to 0.6)
BRUMS mental confusion *(0 to 16)*, mean (SD)	1.2 (2.8)	0.8 (2.0)	0.3 (0.6)	0.2 (0.7)	0.4 (1.0)	0.4 (1.3)	0.4 (0.9)	0.3 (0.8)	0.4 (1.2)	0.5 (1.4)	–0.0 (–0.4 to 0.3)
BRUMS depression *(0 to 16)*, mean (SD)	0.4 (1.2)	0.6 (2.3)	0.1 (0.2)	0.3 (1.5)	0.4 (1.4)	0.6 (1.9)	0.4 (1.8)	0.5 (1.6)	0.5 (1.7)	0.5 (1.6)	–0.1 (–0.6 to 0.4)
BRUMS anger *(0 to 16)*, mean (SD)	0.3 (1.5)	0.5 (1.8)	0.1 (0.2)	0.1 (0.7)	0.1 (0.3)	0.3 (1.1)	0.2 (0.7)	0.5 (1.4)	0.2 (0.9)	0.4 (1.3)	–0.2 (–0.5 to 0.1)
Knee extensor strength *(%)*, mean (SD)	162 (39)	163 (36)	170 (43)	165 (40)	N/A	N/A	180 (38)	177 (41)	N/A	N/A	5 (–3 to 13)
Quadriceps flexibility *(deg)*, mean (SD)	142 (7)	142 (8)	143 (7)	142 (9)	N/A	N/A	142 (7)	140 (9)	N/A	N/A	1 (–1 to 2)
Jump height *(cm)*, mean (SD)	28.7 (8.2)	31.2 (8.8)	27.5 (7.6)	29.1 (7.9)	N/A	N/A	28.0 (7.8)	30.0 (7.6)	N/A	N/A	0.4 (–0.8 to 1.5)

BRUMS = Brunel Mood Scale, Con = control group, Exp = experimental group, N/A = not applicable.

exercise.[31,33] Thus, massage therapy may raise lymphatic and blood flow, accelerating the elimination of catabolites.[9,31,32] Previous studies have also reported positive effects of massage therapy on delayed pain.[7,34,35] Hilbert et al[35] reported that massage therapy applied 2 hours after DOMS induction in the hamstring using eccentric exercise may reduce pain intensity 48 hours after the intervention. Of note, the current study identified lower DOMS intensity compared to previous studies.[11,15,35] This indicates that massage therapy may be effective at mitigating DOMS, regardless of pain level, although the effect was weak in the present study where DOMS intensity was low. Several causal factors have been suggested for DOMS, including muscle damage and the inflammatory process.[31,36] Future investigations should verify the impact of massage therapy on these DOMS-related factors.

Previously, Nunes et al[6] reported that massage therapy is effective at reducing perceived fatigue after strenuous exercise, which was not observed in the present study. In the study by Nunes et al,[6] participants presented a higher fatigue level compared to the present study, which may explain this inconsistency. Perhaps massage therapy is only effective at lowering perceived fatigue in exhausted athletes with important metabolic alterations. Additional research is needed to understand the influence of massage therapy on athlete fatigue and develop clinical prediction rules to determine whether fatigue level is a decisive factor in the effectiveness of massage therapy on muscle fatigue.

In opposition to previous studies,[7,37,38] the current study found that massage therapy had no effect on assessments related to physical performance (flexibility, strength and jump performance). Hopper et al[37] reported that massage therapy may improve hamstring flexibility immediately after application in hockey players; Shin and Sung[38] observed that massage therapy applied after eccentric exercise increased ankle plantar flexion strength in healthy people; and Mancinelli et al[7] found that massage therapy applied 48 hours after a high-intensity training session increased jump height in volleyball athletes. A 10-km run impairs the physical and physiological function of athletes;[39] however, this habitual exercise stimulus may not alter physical performance (flexibility, strength and jump performance) to a degree that requires intervention. As such, massage therapy may not be indicated to recover these cases.

The present study's findings suggest that 10 minutes of massage therapy on the quadriceps after habitual moderate exercise has an immediate (and to a lesser extent a delayed) effect on pain intensity, but that many people would consider the effect too small to bother investing in the massage. The runners did not report disabling pain levels after a 10-km run and the estimates of the effect on pain had confidence intervals that extended to include an effect as small as 0.1, and no other benefits were obtained. Therefore, recreational athletes could be advised that, while massage can be expected to reduce their pain intensity, the effect will be mild and physical performance will not be improved. Some may enjoy the massage as a 'reward' after exercise, and not be concerned about the magnitude of the pain reduction. Such patients may choose to receive massage, and certainly the confidence intervals on all outcomes indicate that no substantial detriment should be anticipated. However, those who seek massage as a means of reducing fatigue or hastening recovery should be advised that such effects would not be anticipated.

This study's findings are limited to runners accustomed to distances of 10 km, with further research needed for athletes of other sports. It would also be interesting to consider additional factors when deciding whether to use massage therapy in athletes with tolerable pain levels, such as fatigue or overtraining risk. Additionally, massage therapy application over several sessions may also have a chronic effect. Future research could investigate the effects of massage therapy applied over several sessions in terms of preventing muscle injuries.

In summary, massage therapy was effective at reducing pain intensity after application to the quadriceps of runners compared to a sham technique, but the magnitude of the effect was small with no flow-on effects on perceived fatigue, flexibility, strength or jump performance. Further research is needed to understand the mechanisms of massage therapy effects on pain and to determine whether the effect of massage therapy depends on the level of fatigue.

What was already known on this topic: In sports, massage is often used to reduce pain and promote physical recovery. Massage can reduce pain and fatigue after very intense, prolonged exercise.
What this study adds: After a habitual 10-km run, massage therapy applied to the quadriceps muscle reduces the intensity of pain, but the effect is mild and may not be considered clinically worthwhile by many people. In this setting, massage therapy does not affect fatigue, mood, quadriceps muscle flexibility, knee extension strength or vertical jump performance.

Footnotes: [a] RS Pro, Corby, UK; [b] My Jump 2 app, version 3.9.5, Madrid, Spain; [c] iPhone 7, Apple Inc, California, USA; [d] Lafayette Instruments, IN, USA; [e] G*Power Version 3.1.9.2, Düsseldorf, Germany; [f] SPSS Inc. Version 17.0, Chicago, IL, USA.

eAddenda: Table 3 and Appendices 1-4 can be found online at DOI: https://doi.org/10.1016/j.jphys.2019.02.006.

Ethics approval: The Human Research Ethics Committee of Universidade do Estado de Santa Catarina approved this study (approval number CAAE 68038817.7.0000.0118). All participants gave written informed consent before data collection began.

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References

1. Bervoets DC, Luijsterburg PAJ, Alessie JJN, Buijs MJ, Verhagen AP. Massage therapy has short-term benefits for people with common musculoskeletal disorders compared to no treatment: a systematic review. *J Physiother.* 2015;61:106–116.
2. Fritz S. *Mosby's Fundamentals of Therapeutic Massage*. 5th ed. St Louis: Mosby; 2012. https://www.elsevier.com/books/mosbys-fundamentals-of-therapeutic-massage/fritz/978-0-323-35374-8. Accessed 31 October, 2018.
3. Moraska A. Sports massage. A comprehensive review. *J Sports Med Phys Fitness*. 2005;45:370–380.
4. Nelson N. Delayed onset muscle soreness: is massage effective? *J Bodyw Mov Ther.* 2013;17:475–482.
5. Poppendieck W, Wegmann M, Ferrauti A, Kellmann M, Pfeiffer M, Meyer T. Massage and performance recovery: a meta-analytical review. *Sports Med*. 2016;46:183–204.
6. Nunes GS, Bender PU, de Menezes FS, Yamashitafuji I, Vargas VZ, Wageck B. Massage therapy decreases pain and perceived fatigue after long-distance Ironman triathlon: a randomised trial. *J Physiother.* 2016;62:83–87.
7. Mancinelli CA, Davis DS, Aboulhosn L, Brady M, Eisenhofer J, Foutty S. The effects of massage on delayed onset muscle soreness and physical performance in female collegiate athletes. *Phys Ther Sport*. 2006;7:5–13.
8. Imtiyaz S, Veqar Z, Shareef MY. To Compare the Effect of Vibration Therapy and Massage in Prevention of Delayed Onset Muscle Soreness (DOMS). *J Clin Diagn Res*. 2014;8:133–136.
9. Weerapong P, Hume PA, Kolt GS. The mechanisms of massage and effects on performance, muscle recovery and injury prevention. *Sports Med*. 2005;35:235–256.
10. Ogai R, Yamane M, Matsumoto T, Kosaka M. Effects of petrissage massage on fatigue and exercise performance following intensive cycle pedalling. *Br J Sports Med*. 2008;42:834–838.
11. Andersen LL, Jay K, Andersen CH, Jakobsen MD, Sundstrup E, Topp R, et al. Acute effects of massage or active exercise in relieving muscle soreness: randomized controlled trial. *J Strength Cond Res*. 2013;27:3352–3359.
12. Lastella M, Roach GD, Halson SL, Martin DT, West NP, Sargent C. The impact of a simulated grand tour on sleep, mood, and well-being of competitive cyclists. *J Sports Med Phys Fitness*. 2015;55:1555–1564.
13. Parry D, Chinnasamy C, Papadopoulou E, Noakes T, Micklewright D. Cognition and performance: anxiety, mood and perceived exertion among Ironman triathletes. *Br J Sports Med*. 2011;45:1088–1094.
14. Arroyo-Morales M, Olea N, Martínez MM, Hidalgo-Lozano A, Ruiz-Rodríguez C, Díaz-Rodríguez L. Psychophysiological effects of massage-myofascial release

after exercise: a randomized sham-control study. *J Altern Complement Med*. 2008;14:1223–1229.
15. Kargarfard M, Lam ETC, Shariat A, Shaw I, Shaw BS, Tamrin SBM. Efficacy of massage on muscle soreness, perceived recovery, physiological restoration and physical performance in male bodybuilders. *J Sports Sci*. 2016;34:959–965.
16. Micklewright D, Griffin M, Gladwell V, Beneke R. Mood State Response to Massage and Subsequent Exercise Performance. *The Sport Psychologist*. 2005;19: 234–250.
17. Hjermstad MJ, Fayers PM, Haugen DF, Caraceni A, Hanks GW, Loge JH, et al. Studies comparing Numerical Rating Scales, Verbal Rating Scales, and Visual Analogue Scales for assessment of pain intensity in adults: a systematic literature review. *J Pain Symptom Manage*. 2011;41:1073–1093.
18. Kim JE, Seo BK, Choi JB, Kim HJ, Kim TH, Lee MH, et al. Acupuncture for chronic fatigue syndrome and idiopathic chronic fatigue: a multicenter, nonblinded, randomized controlled trial. *Trials*. 2015;16.
19. Costa L, Maher CG, McAuley JH, Hancock MJ, de Melo Oliveira W, Azevedo DC, et al. The Brazilian-Portuguese versions of the McGill Pain Questionnaire were reproducible, valid, and responsive in patients with musculoskeletal pain. *J Clin Epidemiol*. 2011;64:903–912.
20. Rohlfs IC, Rotta TM, Luft CD, Andrade A, Krebs RJ, Carvalho TD. Brunel Mood Scale (BRUMS): an instrument for early detection of overtraining syndrome. *Rev Bras Med Esporte*. 2008;14:176–181.
21. Scattone Silva R, Nakagawa TH, Ferreira ALG, Garcia LC, Santos JEM, Serrão FV. Lower limb strength and flexibility in athletes with and without patellar tendinopathy. *Phys Ther Sport*. 2016;20:19–25.
22. Balsalobre-Fernández C, Glaister M, Lockey RA. The validity and reliability of an iPhone app for measuring vertical jump performance. *J Sports Sci*. 2015;33:1574–1579.
23. Harman EA, Rosenstein MT, Frykman PN, Rosenstein RM, Kraemer WJ. Estimation of Human Power Output from Vertical Jump. *J Strength Cond Res*. 1991;5:116.
24. Sterne JAC, White IR, Carlin JB, Spratt M, Royston P, Kenward MG, et al. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *BMJ*. 2009;338:b2393.
25. Wageck B, Nunes GS, Bohlen NB, Santos GM, de Noronha M. Kinesio Taping does not improve the symptoms or function of older people with knee osteoarthritis: a randomised trial. *J Physiother*. 2016;62:153–158.
26. Twisk JW, Smidt N, de Vente W. Applied analysis of recurrent events: a practical overview. *J Epidemiol Community Health*. 2005;59:706–710.
27. Melzack R, Wall PD. Pain mechanisms: a new theory. *Science*. 1965;150:971–979.
28. Field T, Hernandez-Reif M, Diego M, Schanberg S, Kuhn C. Cortisol decreases and serotonin and dopamine increase following massage therapy. *Int J Neurosci*. 2005;115:1397–1413.
29. Morhenn V, Beavin LE, Zak PJ. Massage increases oxytocin and reduces adrenocorticotropin hormone in humans. *Altern Ther Health Med*. 2012;18:11–18.
30. Brummitt J. The Role of Massage in Sports Performance and Rehabilitation: Current Evidence and Future Direction. *N Am J Sports Phys Ther*. 2008;3:7–21.
31. Guyton AC, Hall JE. *Human Physiology and Mechanisms of Disease*. 6th ed. Philadelphia: Saunders; 1996.
32. Peake JM, Nosaka K, Muthalib M, Suzuki K. Systemic inflammatory responses to maximal versus submaximal lengthening contractions of the elbow flexors. *Exerc Immunol Rev*. 2006;12:72–85.
33. Knez WL, Jenkins DG, Coombes JS. Oxidative stress in half and full Ironman triathletes. *Med Sci Sports Exerc*. 2007;39:283–288.
34. Frey Law LA, Evans S, Knudtson J, Nus S, Scholl K, Sluka KA. Massage reduces pain perception and hyperalgesia in experimental muscle pain: a randomized, controlled trial. *J Pain*. 2008;9:714–721.
35. Hilbert JE, Sforzo GA, Swensen T. The effects of massage on delayed onset muscle soreness. *Br J Sports Med*. 2003;37:72–75.
36. Kenney WL, Wilmore JH, Costill DL. *Physiology of Sport and Exercise*. 6th ed. Champaign, IL: Human Kinetics; 2015.
37. Hopper D, Conneely M, Chromiak F, Canini E, Berggren J, Briffa K. Evaluation of the effect of two massage techniques on hamstring muscle length in competitive female hockey players. *Phys Ther Sport*. 2005;6:137–145.
38. Shin MS, Sung YH. Effects of Massage on Muscular Strength and Proprioception After Exercise-Induced Muscle Damage. *J Strength Cond Res*. 2015;29:2255–2260.
39. Wen DY. Risk factors for overuse injuries in runners. *Curr Sports Med Rep*. 2007;6:307–313.