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Research

Massage therapy decreases pain and perceived fatigue after long-distance Ironman triathlon: a randomised trial

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KEY WORDS

Musculoskeletal manipulations
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ABSTRACT

Question: Can massage therapy reduce pain and perceived fatigue in the quadriceps of athletes after a long-distance triathlon race (Ironman)? **Design:** Randomised, controlled trial with concealed allocation, intention-to-treat analysis and blinded outcome assessors. **Participants:** Seventy-four triathlon athletes who completed an entire Ironman triathlon race and whose main complaint was pain in the anterior portion of the thigh. **Intervention:** The experimental group received massage to the quadriceps, which was aimed at recovery after competition, and the control group rested in sitting. **Outcome measures:** The outcomes were pain and perceived fatigue, which were reported using a visual analogue scale, and pressure pain threshold at three points over the quadriceps muscle, which was assessed using digital pressure algometry. **Results:** The experimental group had significantly lower scores than the control group on the visual analogue scale for pain (MD –7 mm, 95% CI –13 to –1) and for perceived fatigue (MD –15 mm, 95% CI –21 to –9). There were no significant between-group differences for the pressure pain threshold at any of the assessment points. **Conclusion:** Massage therapy was more effective than no intervention on the post-race recovery from pain and perceived fatigue in long-distance triathlon athletes. **Trial registration:** Brazilian Registry of Clinical Trials, RBR-4n2sxr. **[Nunes GS, Bender PU, de Menezes FS, Yamashitafuji I, Vargas VZ, Wageck B (2016) Massage therapy decreases pain and perceived fatigue after long-distance Ironman triathlon: a randomised trial. *Journal of Physiotherapy* 62: 83–87]**

Introduction

Ironman is one of the main long-distance triathlon races in the world. About 40 Ironman events take place every year across the globe, with around 2000 athletes participating in each event.[1] In this competition, athletes have to cover a distance of 226 km, which consists of swimming 3.8 km, cycling 180 km and running 42.2 km.[2] It is a strenuous competition that requires high energy expenditure and generates high physical and metabolic stress.[3,4] Because of this stress, Ironman athletes often experience various medical conditions such as dehydration, heat stroke, hyponatraemia, musculoskeletal injuries, hypothermia, skin injuries, fever, hypoglycaemia, diarrhoea and vomiting.[4–7] However, the most common symptoms after a race are pain and muscle fatigue, which are probably caused by muscle damage that induces an inflammatory response and a reduction in energy reserves.[4,8–10] The body parts most affected by pain and fatigue due to constant overload are the lower limbs, mainly around the knees.[11,12]

Therapeutic interventions are used to try to minimise the severity of symptoms in triathletes after strenuous competition, such as massage, cryotherapy and stretching.[13–15] Massage therapy is often used after competitions and is defined as a mechanical manipulation of human body tissue by means of manual compressions and rhythmic percussions.[13,14] Different massage therapy techniques are expected to increase blood and lymphatic flow;[14] theoretically, this might accelerate the elimination of catabolites, which possibly reduces the sensation of fatigue.[14] Another expected effect of massage therapy is pain relief.[14] The mechanical stimulus caused by manual contact on the skin may have a neurological effect, blocking the noxious stimuli based on the gate-control theory.[14] Another possibility is a physiologic effect via the release of β-endorphins.[14]

Several clinical trials have demonstrated the beneficial effects of massage therapy in athletes after strenuous exercises.[16,17] Ogai et al[17] evaluated physically active university students who performed the same protocol through strenuous workout on a stationary bike in two sessions. In one of the sessions, they received massage to the lower limbs for 10 minutes in the middle of the protocol. After the massage protocol session, the participants showed a decrease in muscle stiffness and perceived fatigue, which was evaluated by the visual analogue scale (VAS).[17] Mancinelli et al[16] also verified the effects of massage in athletes. In this study, high school basketball and volleyball players were divided into two groups after the first training session of the season: one group

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rested while the other received massage to the quadriceps muscle on the peak day of delayed onset muscle soreness.[16] The group that received massage showed a decrease in perceived pain and pressure pain threshold and improved vertical jump performance.[16]

Some systematic reviews have been performed to investigate the effects of massage therapy.[13,18] These reviews have concluded that massage therapy can have benefits in a variety of musculoskeletal conditions,[18] including soreness after strenuous exercise.[13] However, among the included studies, there has been some lack of standardisation of the techniques applied during the massage therapy. Furthermore, the intense physical activities used in these studies were generally high-intensity exercise regimens designed to bring on rapid fatigue. The studies were also not conducted in real competition situations, and the massage intervention was not always administered immediately after the exercise. Therefore, questions remain regarding the effectiveness of massage after very prolonged, strenuous sporting competitions such as long-distance triathlon.[13]

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

Does massage reduce pain and fatigue in the quadriceps of athletes after a long-distance triathlon race (Ironman)?

Method

Design

This was a randomised clinical trial in which the participants were allocated to one of two groups: an experimental group or a control group. The experimental group received massage to the quadriceps, which was aimed at recovery after competition, and the control group rested in a sitting position. 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 and centre

Seventy-four triathlon athletes from Ironman Brazil took part in this study. To be eligible for inclusion in the study, athletes had to complete the entire Ironman triathlon race and report to the physiotherapy clinic with their main complaint being pain in the anterior portion of the thigh. The exclusion criteria were any medical conditions that were not compatible with the procedures of the study, such as: severe metabolic and respiratory disorders during the study procedures, cramps during the evaluations and/or interventions, presence of abrasions on the thigh, or any change in sensation of the thigh caused by analgesics or cryotherapy.

The evaluations and interventions of this study were conducted in the physiotherapy clinic of the Ironman Brazil triathlon competition. This clinic was located near the finish line. First, the athletes were assessed to determine if they met the eligibility criteria, and data about their baseline characteristics were collected. The measurements were taken from the most painful quadriceps, as reported using the VAS. If the participant reported the same level of pain in both thighs, the side to be treated was randomly selected by flipping a coin. After the first evaluation, the participants were allocated to a group and directed to the intervention site. After the interventions, the same blind researcher reassessed the participants and, if needed, they were directed back to the clinic to continue the treatment. To maintain the assessor blinding, the evaluation was conducted in a different place to where the massage intervention was conducted, the assessor was not informed of who was in which group and the foam used to reduce friction during the massage was also applied on the quadriceps of the control participants.

Intervention

The experimental group received massage for 7 minutes from a therapist who was not involved in the measurements. 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; 2 minutes of deep effleurage, in which the therapist performed the same movement but applied more pressure to the thigh; 2 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 1 minute of superficial effleurage to finish the intervention. A video demonstration of the techniques is presented in Appendix 1 (see eAddenda for Appendix 1).

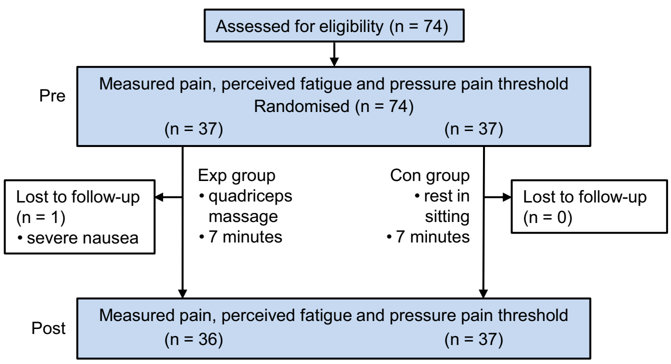

Figure 1. Design and flow of participants through the study.
Exp = experimental group, Con = control group.

Massage therapy techniques.

Foam made from soap and water was used to reduce friction between the therapist's hands and the participant's skin.

The control group rested in a sitting position for 7 minutes. This control was adopted because minimum manual contact from a sham technique could have similar effects to those of the experimental intervention. The participants allocated to the control group were not informed that they would not receive massage; they were told to expect an available therapist to perform the massage. At the end of this waiting period, the same foam used in the massage intervention was applied to the participants' leg in order to keep the evaluator blinded to group allocation. After the final measures, participants were led to the physiotherapy clinic to complete the treatment.

Outcome measures

Pain and perceived fatigue

The pain and perceived local fatigue in the quadriceps muscle were measured using the VAS. The scale consisted of a 100-mm line on which 0 mm indicated no pain or fatigue and 100 mm indicated the worst possible pain or extreme exhaustion. The participants were asked to score the intensity of pain and fatigue at that time on the horizontal 100-mm line.[17,19] The levels of pain and fatigue were measured separately in mm. The VAS has high reliability for acute pain measures, with an intraclass correlation coefficient (ICC) of 0.97,[20] and is also validated to measure fatigue in healthy subjects.[21]

Pressure pain threshold

To measure the pressure pain threshold, a digital pressure algometer[a], which was connected to a computer for data collection, was used. Algometry has been shown to be highly reliable (ICC = 0.91).[22] The participant sat with the knee flexed at 90 deg and feet flat on the floor. Three points were measured at the quadriceps: the muscle bellies of the rectus femoris, vastus lateralis and vastus medialis. The algometer inductor was positioned perpendicularly to the skin at each point and gradual pressure was applied until the participant reported a change from the sensation of pressure to pain. At that point, the pressure was stopped immediately and the highest pressure that was recorded represented the pain threshold.[16,22] Before the beginning of the evaluation, the subject was familiarised with the measurement by a demonstration of the pressure at each point to be measured. The measure in each point and mean among points were used for analysis. Pressure was measured in kgf/cm^2.

Table 1
Characteristics of participants.

Characteristic	Exp (n = 37)	Con (n = 37)
Age *(yr)*, mean (SD)	37 (7)	39 (11)
Gender, n males (%)	34 (92)	36 (97)
Height *(m)*, mean (SD)	1.77 (0.09)	1.77 (0.08)
Weight *(kg)*, mean (SD)	75.5 (10.6)	77.2 (10.8)
Time to complete race *(hh:mm)*, mean (SD)	11:31 (2:17)	12:25 (2:16)
Complications during race, n participants (%)		
cramps	13 (35)	11 (30)

Exp = experimental group, Con = control group.

Data analysis

The sample size of this study was calculated based on statistical power of 80% and an alpha of 5%. The sample size calculation indicated that 36 participants in each group would be required to identify: a between-group difference in pain of 20 mm measured by the VAS, with a SD of 30 mm;[16] a between-group difference of 10 mm in the perceived fatigue measurement by the VAS, with a SD of 15 mm;[17] and a between-group difference of 1.0 kgf/cm^2 in the pressure pain threshold measurement, with a SD of 1.5 kgf/cm^2 based on a pilot study.

To compare the effect of massage between the experimental and control groups, the independent t-test was used to identify differences. The difference from baseline was taken into account in the analysis. A level of significance of $p \leq 0.05$ was adopted for all tests and the data were analysed with an intention-to-treat approach. The 'last observation carried forward' approach was used for missing data. The effect size (Cohen's d) was calculated and classified as small ($d = 0.2$), moderate ($d = 0.5$), and large ($d \geq 0.8$).[23] The analyses and sample size calculation were performed using commercially available software[b,c].

Results

Flow of participants through the study

One participant did not finish the procedures due to nausea during the initial evaluation, necessitating medical care. Thus, 36 participants in the experimental group and 37 participants in the control group completed the procedures. The characteristics of participants are shown in Table 1 and in the first two columns of data in Table 2. Individual participant data are presented in Table 3 (see eAddenda for Table 3). The only complication reported by some participants during the competition was the occurrence of cramps.

Compliance with the study protocol

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

Effect of the massage intervention

The independent t-test showed statistically significant between-group differences after intervention for pain and perceived fatigue, which were evaluated using the VAS (Table 2). The experimental group had lower scores on the VAS for pain, by a mean of 7 mm (95% CI 1 to 13). The experimental group also had

Table 2
Mean (SD) of groups, mean (SD) difference within groups, and mean (95% CI) difference between groups.

Outcome	Groups				Difference within groups		Difference between groups	Effect size (Cohen's d)
	Pre		Post		Post minus Pre		Post minus Pre	
	Exp (n = 37)	Con (n = 37)	Exp (n = 36)	Con (n = 37)	Exp	Con	Exp minus Con	
Pain *(mm)*	58 (24)	62 (23)	48 (24)	59 (23)	–10 (12)	–3 (13)	–7 (–13 to –1)	0.6
Perceived fatigue *(mm)*	84 (18)	79 (23)	69 (24)	79 (19)	–15 (14)	0 (1)	–15 (–21 to –9)	1.5
PPT *(kgf/cm^2)*								
rectus femoris	6.0 (2.4)	6.1 (2.7)	5.6 (2.2)	5.5 (3.0)	–0.4 (1.7)	–0.6 (1.3)	0.1 (–0.6 to 0.8)	0.1
vastus lateralis	5.4 (1.7)	5.4 (2.1)	5.2 (1.8)	5.1 (2.2)	–0.1 (1.2)	–0.4 (1.1)	0.2 (–0.3 to 0.7)	0.3
vastus medialis	4.4 (1.4)	4.5 (1.4)	4.2 (1.5)	4.4 (1.7)	–0.2 (1.0)	0.0 (1.0)	–0.2 (–0.6 to 0.3)	0.2
quadriceps femoris	5.3 (1.7)	5.3 (2.0)	5.0 (1.7)	5.0 (2.2)	–0.3 (1.0)	–0.3 (0.8)	0.1 (–0.4 to 0.5)	0.0

Exp = experimental group, Con = control group, PPT = pressure pain threshold.

lower scores on the VAS for perceived fatigue, by a mean of 15 mm (95% CI 9 to 21).

There were no significant between-group differences for the pressure pain threshold in any of the measured points. When the average of the three measured points was compared between groups, the difference was again non-significant (Table 2).

The effect size was large for perceived fatigue, moderate for pain, and small for pain evaluated by algometer at all measured points (Table 2).

Discussion

This study aimed to determine whether massage therapy could optimise the recovery of athletes after competing in a long-distance triathlon such as Ironman. Both pain and fatigue are very common conditions after these competitions.[10] The onset of muscle pain and discomfort may result from the activity overload. This may lead to structural damage, which leads to an inflammatory response in the muscle tissue,[4,10,24] and this inflammatory response stimulates the nerve endings (deep nociceptors), which results in painful stimuli.[25] The perception of fatigue may be related to the high energy demands of this kind of sport. The shortage of energy substrate, mainly muscle glycogen, may lead to metabolic acidosis (resulting from organic reactions to energy production)[25,26] and increased production of free radicals that are generated by the oxidative damage in the body cells.[3] Thus, the lack of nutrients for energy generation and the accumulation of catabolites may cause a decrease in capacity for strength and power generation in the energy transfer system and a disturbance in the transmission of nerve impulses.[25,27]

Massage therapy as a technique for triathlete recovery after a long-distance race resulted in decreased pain and perceived fatigue when compared with triathletes who remained at rest in this study. When calculated in terms of a Cohen's *d*, the effect size could be categorised as large for perceived fatigue and moderate for pain. When considered in mm on the 0-to-100 mm VAS, the 7-mm effect on pain and the 15-mm effect on perceived fatigue would not be considered large or perhaps even moderate. However, it should be noted that the massage was only applied for 7 minutes. This raises two important issues. First, athletes may consider these relatively small improvements worthwhile given the small amount of time invested in the intervention. Second, although 7 minutes of massage was sufficient to demonstrate that massage improves pain and perceived fatigue in these long-distance triathletes, massage of greater duration may be able to increase the magnitude of these effects.

Massage therapy was applied in this study in order to mitigate the main structural and physiological damage after long-distance triathlon events. Some studies suggest that the manual contact can cause physiological, neurological or psychological responses for the control of pain sensation.[14] In the present study, the experimental group showed decreased perception of pain, but the pressure pain threshold remained unchanged. This suggests that massage results cannot be explained by neurological responses based on the gate control theory. Possible explanations may be related to physiological responses through the β-endorphin release or catabolite elimination or to psychological pathways where attention and manual contact can lead to a sense of well-being.[14]

The physiological responses obtained through massage are enhanced by the improvement observed in the experimental group regarding perceived fatigue. In physiological terms, fatigue relates to the decrease in normal function.[28] It has also been suggested that fatigue can have both central and peripheral sources, with lack of energy substrate and metabolic waste concentration being the most probable causes.[14,26,28] Thus, it can be assumed that the positive effects of massage therapy on perceived fatigue are related to greater localised blood circulation either by mechanical effect or temperature increase,[14,29,30] which aid in the removal of metabolic waste.[14,30]

As discussed above, systematic reviews have been performed to analyse the results of studies about the effects of massage therapy. Bervoets et al included studies that assessed the effects of massage therapy on participants with musculoskeletal disorders, and concluded that massage therapy as a stand-alone intervention reduces pain and improves function.[18] Another systematic review by Best et al included only studies about sports massage therapy; it concluded that massage therapy could assist in muscle recovery and reduce delayed onset muscle soreness.[13] Thus, the results of the present study are in agreement with the conclusions of those systematic reviews, especially with respect to the effect on pain, despite the large variety of massage techniques applied in the analysed studies.

Despite the positive effects of massage on pain and fatigue in the present study, these findings should be analysed with caution. The positive effects were found only in subjective measures. Another consideration is that the time between evaluation and re-evaluation was very short, and this could also have had some influence on the results. Another issue was the lack of a sham technique as control. Although this did not control for the effects of contact with the therapist, this lack of control was judged to be a less important consideration than the potential for the minimal manual contact from a sham technique to have led to similar effects as massage. Despite this issue, the results still confirm the effect of the massage on well-being and relief of symptoms in the short term, even if it does not have a significant effect on structural and physiological aspects of post-exercise soreness.

Based on the results of the present study, it can be concluded that the massage therapy techniques used were more effective in the recovery from pain and perceived fatigue than no intervention after a long-distance triathlon race. Further investigations are needed to verify the acute effects of massage therapy on metabolic stress and biochemical markers of structural damage in athletes after strenuous competitions and to identify the effects of massage therapy applied at the end of competitions on the recovery of long-term athletes.

In summary, there is now direct evidence to support the use of massage for the recovery of triathletes after long-distance endurance races. Research on massage therapy applied at the end of such competitions is important because this technique is widely used in this context and there is the potential to identify effects of greater magnitude (eg, by increasing the dose of massage delivered).

What is already known on this topic: Pain and fatigue are common after intense exercise. Massage is beneficial in this situation, but the evidence for its benefits comes from studies of controlled periods of intense exercise designed to cause rapid onset of fatigue.
What this study adds: Among people who had just competed in a 226-km Ironman event, a short period of massage over the quadriceps resulted in local reductions in both pain and perceived fatigue. The amount of pressure over the quadriceps required to elicit pain was not significantly reduced by the massage.

Footnotes: [a]EMG System do Brasil, model EMG230C, São Paulo, Brazil. [b]SPSS Inc. Version 17.0, Chicago, IL, USA. [c]G*Power Version 3.1.9.2, Düsseldorf, Germany.

eAddenda: Table 3 and Appendix 1 (video) can be found online at doi:10.1016/j.jphys.2016.02.009.

Ethics approval: The Human Research Ethics Committee of Universidade do Estado de Santa Catarina approved this study (approval number CAAE: 15225113500000118). All participants gave written informed consent before data collection began.

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References

1. Ironman triathlon 140.6 & 70.3. Ironman Official site. http://www.ironman.com [accessed 9/12/2014].
2. Babbitt B, Lampley J. *30 Years of the Ironman Triathlon World Championship.* Aachen; Hove: Meyer & Meyer Fachverlag und Buchhandel GmbH; 2008.
3. Knez WL, Jenkins DG, Coombes JS. Oxidative stress in half and full Ironman triathletes. *Med Sci Sports Exerc.* 2007;39:283–288.
4. O'Toole ML, Douglas PS. Applied physiology of triathlon. *Sports Med.* 1995;19: 251–267.
5. Hew TD, Chorley JN, Cianca JC, Divine JG. The incidence, risk factors, and clinical manifestations of hyponatremia in marathon runners. *Clin J Sport Med.* 2003;13: 41–47.
6. Holtzhausen LM, Noakes TD. Collapsed ultraendurance athlete: proposed mechanisms and an approach to management. *Clin J Sport Med.* 1997;7:292–301.
7. Roberts WO. A 12-yr profile of medical injury and illness for the Twin Cities Marathon. *Med Sci Sports Exerc.* 2000;32:1549–1555.
8. García-Manso JM, Rodríguez-Ruiz D, Rodríguez-Matoso D, de Saa Y, Sarmiento S, Quiroga M. Assessment of muscle fatigue after an ultra-endurance triathlon using tensiomyography (TMG). *J Sports Sci.* 2011;29:619–625.
9. Geva N, Defrin R. Enhanced pain modulation among triathletes: a possible explanation for their exceptional capabilities. *Pain.* 2013;154:2317–2323.
10. Neubauer O, König D, Wagner K-H. Recovery after an Ironman triathlon: sustained inflammatory responses and muscular stress. *Eur J Appl Physiol.* 2008;104:417–426.
11. Korkia PK, Tunstall-Pedoe DS, Maffulli N. An epidemiological investigation of training and injury patterns in British triathletes. *Br J Sports Med.* 1994;28:191–196.
12. Gosling CM, Gabbe BJ, Forbes AB. Triathlon related musculoskeletal injuries: The status of injury prevention knowledge. *J Sci Med Sport.* 2008;11:396–406.
13. Best TM, Hunter R, Wilcox A, Haq F. Effectiveness of sports massage for recovery of skeletal muscle from strenuous exercise. *Clin J Sport Med.* 2008;18:446–460.
14. 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.
15. Silveira MA, Haupenthal A, Mannrich G, Torres SF. Atuação Fisioterapêutica No Ironman Brasil. *Fisioterapia em Movimento.* 2006;19:35–40.
16. 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.
17. 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.
18. 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.
19. Sellwood KL, Brukner P, Williams D, Nicol A, Hinman R. Ice-water immersion and delayed-onset muscle soreness: a randomised controlled trial. *Br J Sports Med.* 2007;41:392–397.
20. Bijur PE, Silver W, Gallagher EJ. Reliability of the visual analog scale for measurement of acute pain. *Acad Emerg Med.* 2001;8:1153–1157.
21. Lee KA, Hicks G, Nino-Murcia G. Validity and reliability of a scale to assess fatigue. *Psychiatry Res.* 1991;36:291–298.
22. Chesterton LS, Sim J, Wright CC, Foster NE. Interrater reliability of algometry in measuring pressure pain thresholds in healthy humans, using multiple raters. *Clin J Pain.* 2007;23:760–766.
23. Cohen J. A power primer. *Psychol Bull.* 1992;112:155–159.
24. 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.
25. Wilmore JH, Costill DL, Kenney WL. *Physiology of Sport and Exercise*. 4th ed. Champaign, IL: Human Kinetics; 2008.
26. Westerblad H, Allen DG, Lännergren J. Muscle fatigue: lactic acid or inorganic phosphate the major cause? *News Physiol Sci.* 2002;17:17–21.
27. Enoka RM, Duchateau J. Muscle fatigue: what, why and how it influences muscle function. *J Physiol.* 2008;586:11–23.
28. Marino FE, Gard M, Drinkwater EJ. The limits to exercise performance and the future of fatigue research. *Br J Sports Med.* 2011;45:65–67.
29. Portillo-Soto A, Eberman LE, Demchak TJ, Peebles C. Comparison of blood flow changes with soft tissue mobilization and massage therapy. *J Altern Complement Med.* 2014;20:932–936.
30. Wiltshire EV, Poitras V, Pak M, Hong T, Rayner J, Tschakovsky ME. Massage impairs postexercise muscle blood flow and "lactic acid" removal. *Med Sci Sports Exerc.* 2010;42:1062–1071.