Effectiveness of Sports Massage for Recovery of Skeletal Muscle From Strenuous Exercise

Thomas M. Best, MD, PhD, Robin Hunter, DC,* Aaron Wilcox, BS,† and Furqan Haq, PhD**

Objective: Sport massage, a manual therapy for muscle and soft tissue pain and weakness, is a popular and widely used modality for recovery after intense exercise. Our objective is to determine the effectiveness of sport massage for improving recovery after strenuous exercise.

Data Sources: We searched MEDLINE, EMBASE, and CINAHL using all current and historical names for sport massage. Reference sections of included articles were scanned to identify additional relevant articles.

Study Selection: Study inclusion criteria required that subjects (1) were humans, (2) performed strenuous exercise, (3) received massage, and (4) were assessed for muscle recovery and performance. Ultimately, 27 studies met inclusion criteria.

Data Extraction: Eligible studies were reviewed, and data were extracted by the senior author (TMB). The main outcomes extracted were type and timing of massage and outcome measures studied.

Data Synthesis: Data from 17 case series revealed inconsistent results. Most studies evaluating post-exercise function suggest that massage is not effective, whereas studies that also evaluated the symptoms of DOMS did show some benefit. Data from 10 randomized controlled trials (RCTs) do, however, provide moderate evidence for the efficacy of massage therapy. The search identified no trend between type and timing of massage and any specific outcome measures investigated.

Conclusions: Case series provide little support for the use of massage to aid muscle recovery or performance after intense exercise. In contrast, RCTs provide moderate data supporting its use to facilitate recovery from repetitive muscular contractions. Further investigation using standardized protocols measuring similar outcome variables is necessary to more conclusively determine the efficacy of sport massage and the optimal strategy for its implementation to enhance recovery following intense exercise.

Submitted for publication November 5, 2007; accepted July 27, 2008.
From the *Division of Sports Medicine, Department of Family Medicine, The Ohio State University, Columbus, Ohio; and †College of Medicine, The Ohio State University, Columbus, Ohio.
The authors state that they have no financial interest in the products mentioned within this article.
Reprints: Furqan Haq, PhD, The Ohio State University Sport Medicine Center, 2050 Kenny Road, Columbus, OH 43221 (e-mail: furqan.haq@osumc.edu).

Key Words: massage, sport, soft tissue, exercise, muscle, recovery, performance

(*Clin J Sport Med* 2008;18:446–460)

INTRODUCTION

Massage has been defined as "a mechanical manipulation of body tissues with rhythmical pressure and stroking for the purpose of promoting health and well-being".[1] A variety of techniques and modalities, including massage, are used clinically to enhance recovery after exercise-induced muscle damage. In fact, up to 45% of total time in physiotherapy for sport-related injury and performance consists of massage treatments.[2] On the basis of experiences and observations, coaches, athletes and sports medicine personnel hold the belief that massage provides a variety of benefits to the body.[3] According to the American Massage Therapy Association (AMTA, http://www.amtamassage.org), the physical benefits of therapeutic massage on muscle include relief of muscle tension and stiffness, faster healing of strained muscles and sprained ligaments, reduced muscle pain, swelling and spasm, greater joint flexibility and range of motion, and even enhanced athletic performance. It has also been suggested that massage increases muscle blood flow and lactate clearance[4] while decreasing creatinine kinase (CK) levels.[5]

Evidence to support or refute its effects on sports performance is insufficient at this time, but a recent report advances our understanding of massage and its potential role in exercise-related muscle pain.[6] The importance of factors such as therapist experience may also be an important consideration in predicting the efficacy of this therapy.[6] Therefore, the contrast between current scientific understanding of sports massage and its practice is notable, and scientific evidence to corroborate or refute an effect of massage on muscle recovery remains an important area of investigation.[6]

Despite the fact that massage has been around for thousands of years, scientists and clinicians still do not fully understand what changes occur in the body during massage, whether they influence health, and, if so, how (nccam.nih.gov/health/massage). Clinicians who use sport massage typically employ a number of techniques. A particularly common technique is Swedish massage, which includes a combination of effleurage, petrissage, friction, vibration, and percussion. One of the most common indications for sport massage is the treatment of muscle pain and weakness associated with delayed onset muscle soreness (DOMS). DOMS describes muscle pain and weakness that typically develop 24 hours after eccentric exercise, particularly if the exercise is unfamiliar to the subject.[7] DOMS peaks between 24 hours and 72 hours after exercise and usually subsides within 5 to 7 days; however, this time period of decreased function can be of great significance to athletes.[8] Given the theoretical potential for sport massage to accelerate recovery and improve performance and the increasing frequency with which it is being used (nccam.nih.gov/health/massage), we undertook a systematic review to determine its effectiveness to enhance recovery after intense exercise.

METHODS

The search was conducted in September 2007 using 3 databases (MEDLINE, EMBASE, and CINAHL) for all years between 1950 and 2007 without language or data restriction. The authors scanned the reference sections of articles meeting initial criteria. Articles were selected for inclusion in the review if the subjects met the following criteria: (1) were humans, (2) performed strenuous exercise, (3) received massage by hand, and (4) were assessed for muscle recovery and performance. Post-exercise muscle recovery was used to measure the effectiveness of sports massage. Muscle recovery was assessed qualitatively by intensity of muscle soreness and the subjective feeling of pain and quantitatively by range of motion, muscle peak torque, and muscle circumference.

All articles meeting the search strategy were extracted and assessed descriptively by the senior author (TMB). The methodological strength of each RCT was assessed by the Delphi scoring system.[9] Three unblinded authors (TMB, FH, RH) assessed each study, with disagreement resolved by consensus.

RESULTS

The search strategy produced a total of 4022 reference articles (summarized in Table 1). The inclusion and exclusion of articles from the literature review is shown in Figure 1. A total of 27 relevant articles were located; 17 were case series, and 10 were RCTs. The wide variety of massage protocols (type, duration, and frequency), limb treated, and outcome measured made pooling of the data impossible. An inter-rater agreement on RCT quality scoring was not formally assessed; however, there were no significant disagreements between the 3 raters.

Case Series

Massage was performed on the leg in 13 studies, on the arm in 3, and on the back in 1 (Table 2). Report quality and methods varied significantly. The variety of muscle groups used, massage technique, outcome measures, and definitions for eccentric exercise made comparison between studies especially hard. The most common outcome measures were muscle soreness, isometric strength, peak torque, heart rate, blood lactate levels, and blood flow. In 14 of the case studies, massage consisted of effleurage and stroking, and in 1 case kneading and stroking were the main techniques employed. Furthermore, massages were performed in 13 studies within 15 minutes of exercise and within 1 study in each of 1, 2, 3, and 24 hours after exercise. The total number of sessions also varied between studies. No common trend was observed when comparing the effect of massage type and duration on different muscle groups or the observed outcomes. None of the studies reported any adverse effects due to strenuous exercise or administration of massage. Collectively, these 17 studies tended to suggest that physiological benefits of sport massage for recovery and performance enhancement should be questioned.

Case Series Examining Post-exercise Function Only (10 Studies)

Muscle peak torque, sit and reach test, and force production of knee extensors (performance), lactate removal, blood flow, and electromyography (physiological effects) were investigated as outcome variables in these 10 studies.[4,10–18] In only 2 reports, massage after eccentric exercise resulted in improved quadriceps function as defined by maximum leg extension[11] and peak concentric torque.[16]

Case Series Investigating Post-exercise Function and DOMS (7 Studies)

In 7 studies, the symptoms of DOMS were also measured.[7,19-24] Four studies reported that massage did

TABLE 1. Ovid MEDLINE Search Strategy from 1950 to 2007

No	Search Strategy	Results MEDLINE	Results EMBASE	Results CINAHL
1	(((muscle) AND ((strength) OR (performance))) OR (muscle strength) OR (muscle performance) OR ((strenuous exercise) OR ((strenuous) AND (exercise))) OR ((strength training) OR ((strength) AND (training))))	44016	46633	9570
2	(enhanced recovery) OR (improved recuperation) OR (((enhanced) OR (improved)) AND ((recovery) OR (recuperation))) OR ((exhaustive sports) OR ((exhaustive) AND (sports)))	21994	18997	1535
3	((massage) OR (acupressure) OR (soft tissue massage) OR (manual therapy) OR (neuromuscular therapy) OR (((manual) OR (neuromuscular)) AND (therapy)))	62127	15114	9340
4	(#1 OR #2) AND #3	3233	573	408
5	Limit #4 to humans	3088	533	401
6	Total all databases (MEDLINE + EMBASE + CINAHL)		4022	

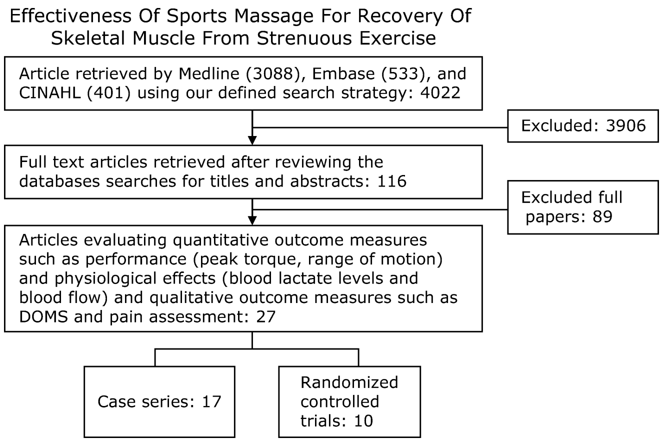

FIGURE 1. Flow diagram of literature filtering process. A total of 3906 articles were excluded as the title or the abstract clearly indicated that they were not relevant, and 89 articles were further excluded because they did not evaluate functional muscle strength, physiological effects, or pain.

decrease the subjective symptoms of DOMS.[7,19–21] Zainuddin et al noted that massage was effective in alleviating DOMS by approximately 30% despite no effect on muscle function.[7] Farr et al found that subjects showed significant increases in soreness and tenderness for the nonmassaged limb 24 hours after a downhill walk.[19] Tanaka et al observed a significant difference between massage and rest groups on a visual analog scale for muscle fatigue, but these findings could not be validated by electromyography.[20] Similarly, Hemmings et al reported that massage produced psychological benefits but no physiological improvements on post-exercise recovery and repeated sports performance.[21] Two studies observed that massage was not effective in alleviating the symptoms of DOMS.[22,23] Hart et al noted no interaction between sport massage and pain levels after eccentric lower leg exercise.[22] Jonhagen et al found that massage did not affect the level or duration of pain after exercise.[23] In only 1 study, massage significantly lowered perceived level of DOMS at 48 hours after exercise but not at other recorded time intervals.[24]

RCTs

A summary of the 10 RCTs (Table 3), including 246 adult subjects (18 to 51 years old), offer the most detailed assessment to date for the efficacy of sport massage to enhance recovery from exercise. The majority of studies compared healthy, non-trained subjects receiving massage after eccentric exercise to control subjects treated with rest only. Massage was performed on the leg in 6 of these studies and on the arm in the remaining studies. The most common outcome measures included peak torque, maximum voluntary muscle contractions, blood lactate levels and serum neutrophil count. All 10 RCTs included effleurage in their massage protocol, while varying on other additional strokes. There was no standardization of the massage protocols. Seven studies used massage within 15 minutes of exercise, two delayed until 2 hours after exercise and 1 approximately 24 hours after exercise. Length of session varied from 5 to 30 minutes with 1 to 4 sessions. No study attempted to quantify the forces applied to the limbs during the massage. Adverse effects were not reported in any of the RCTs as part of the exercise or massage protocols. Collectively, these studies demonstrated no correlation between type of massage and duration on the outcome. Overall, methodological quality was moderate with Delphi scores ranging from 2 to 6. Common methodological limitations included small sample sizes, lack of equivalence across treatment and control groups, and inadequate blinding of assessors.

RCTs Examining Post-Exercise Function Only (4 Studies)

Brooks et al reported on the benefits of manual massage given immediately after 3 minutes of maximal hand exercise that reduced muscle strength to at least 60% of baseline.[25] It was observed that manual massage of the forearm was associated with improved immediate post-exercise grip performance. Martin et al studied the effect of a 5-minute massage on venous blood lactate clearance after a bout of supermaximal leg exercise.[26] No significant difference was found between massage and rest for changes in blood lactate concentration. Lane et al studied the effect of active recovery, massage, and cold water immersion on cycle ergometer output after 2 high-intensity cycling sessions.[27] It was noted that a combination of these 3 modalities facilitated recovery between 2 cycling bouts separated by 24 hours. Monedero et al[28] investigated massage with other recovery treatments on trained cyclists after intense cycling sessions. It was found that a combination of massage and active recovery provided the most effective blood lactate removal. However, massage alone as a recovery therapy was not significantly different than passive rest (control).

RCTs Investigating Post-exercise Function and DOMS (6 Studies)

Smith et al assessed DOMS and CK levels before exercise and intermittently between 8 and 120 hours after exercise.[5] A trend analysis found that the massage group reported reduced levels of DOMS and displayed lower CK levels. Hilbert et al assessed peak torque, range of motion, and DOMS at various intervals between 2 to 48 hours after eccentric exercise-induced muscle injury.[29] Massage administered 2 hours after the bout of exercise did not improve hamstring function, despite a decreased intensity of soreness 48 hours after exercise. Rodenburg et al reported on the effect of a protocol combining warm-up and stretching before eccentric exercise with massage afterwards on DOMS and several functional and biochemical parameters.[30] This intervention significantly improved torque output and elbow range of motion. However, the use of massage did not significantly aid in relieving the symptoms of DOMS. Weber et al tested the impact of therapeutic massage, aerobic exercises, or microcurrent electrical stimulation on muscle soreness and force deficits evident after a high-intensity exercise bout.[31] Significant increases in soreness rating and significant decreases in force generated were found when the initial measures were compared with 24- and 48-hour results for all the 3 treatment modalities, including massage. A study

TABLE 2. A Summary of 17 Case Series

1st Author	Subject Type	Type of Massage	Outcome Measures	Exercise Magnitude and Frequency	Study Design	Number and Timing of Massage Sessions	Results	Conclusions
Farr T[19]	8 healthy, active, and untrained male volunteers with no previous serious medical illness	Effleurage and petrissage	Baseline DOMS, isometric (IMS), and isokinetic strength (IKS) compared post downhill walk (PDW)	40-minute downhill treadmill walk carrying a load 10% of their body mass	Identical criterion test performed on subject's both legs. Subject's one randomly selected leg served as the nonmassaged control, and the other leg was massaged	1 session, 30-minute massage 2 hours after completion of the walk protocol on selected leg	DOMS at 1 and 120 hours PDW = 2.45 ± 0.2 and 1.30 ± 0.1 (control); 2.05 ± 0.2 and 1.25 ± 0.1 (massage). IMS/IKS (% of baseline) at 1 and 120 hours PDW = 92 ± 3/93 ± 5 and 99 ± 4/99 ± 4 (control); 99 ± 3/95 ± 4 and 104 ± 1/103 ± 3 (massage)	Therapeutic massage may attenuate early soreness associated with DOMS but did not significantly ($P > 0.05$) improve IMS and IKS
Hart J[22]	Healthy college-aged individuals (10 men and 9 women) with no recent history of orthopedic injury	Repeating cycles of petrissage and effleurage	Girth measurements (GM) at 5.05, 10.16, 15.24 and 20.32 cm below knee joint line (BKJL) and pain assessed with a visual analog scale (VAS)	Triceps surae contractions at 90% of estimated concentric, 1-repetition max. wt	All subjects performed the interventions. Subject's own leg served as the control while the other leg received massage	5-minute massage sessions at 24, 48, and 72 hours after 4 eccentric exercise sessions	GM (cm) day-4 at 5.05, 10.16, 15.24, and 20.32 cm BKJL = 35.68 ± 3.5, 37.55 ± 3.4, 35.51 ± 3.6, and 30.09 ± 3.3 (control); 35.54 ± 3.4, 37.08 ± 3.4, 35.18 ± 3.3, and 30.53 ± 3.3 (massage). VAS day-4 = 4.34 ± 3.2 (control); 3.51 ± 3.0 (massage)	Massage did not significantly ($P > 0.05$) reduce girth or pain in the lower leg up to 72 hours after eccentric exercise

(*continued on next page*)

TABLE 2. (*continued*) A Summary of 17 Case Series

1st Author	Subject Type	Type of Massage	Outcome Measures	Exercise Magnitude and Frequency	Study Design	Number and Timing of Massage Sessions	Results	Conclusions
Jonhagen S[23]	8 men and 8 women with no injuries at time of study and exercised at least 2 to 3 times per week	Effleurage and petrissage	Maximal strength (MS) and functional tests based on 1-leg long jumps (LJ). Pain evaluated using VAS before, immediately after exercise (IAE) and 2 days after exercise (2d AE)	300 maximal eccentric contractions of the quadriceps muscle bilaterally	All subjects performed the interventions. Subject's one leg served as the treatment, and the nonmassaged leg served as the control	First session within 10 minutes of exercise for 12 mins on randomly chosen leg and then once daily for 2 days	MS (Nm) IAE and 2d AE = 73 ± 38 and 86 ± 37 (control); 75 ± 36 and 89 ± 32 (massage). LJ (cm) IAE and 2d AE = 142 ± 36 and 154 ± 31 (control); 143 ± 44 and 157 ± 41 (massage). VAS IAE and 2d AE = 2.1 ± 3.0 and 3.2 ± 3.0 (control); 2.2 ± 3.0 and 3.1 ± 2.5 (massage)	Massage treatment did not significantly ($P > 0.05$) affect pain or the loss of strength or function after exercise
Tiidus PM[24]	9 healthy university-aged volunteers (5 men and 4 women) performing no regular physical activity	Superficial and deep effleurage strokes	Quadriceps peak torque (PT) at 0, 60, and 180 degrees$\cdot$sec^{-1} and DOMS after exercise (AE)	7 sets of 20 quadriceps maximum contractions between knee angles 180 degrees and 90 degrees at 90 degrees$\cdot$sec^{-1}	All subjects performed the interventions. Subject's one leg randomly selected as the treatment, and the other as control	First session, 10-min massage within 1 hour AE and repeated similar sessions at 24 and 72 hours AE	PT at 0, 60, and 180 degrees$\cdot$sec^{-1} 15 minutes/4 days AE = 68 ± 6/79 ± 9, 62 ± 8/69 ± 7, and 62 ± 7/58 ± 6 (control); 67 ± 5/79 ± 5, 57 ± 7/76 ± 4, and 57 ± 6/69 ± 4 (massage). DOMS 1, 2, 3, and 4 days AE = 5.9 ± 0.7, 6.1 ± 0.9, 3.1 ± 1.0, and 2.0 ± 0.7 (control); 6.8 ± 0.6, 5.0 ± 0.5, 2.7 ± 0.5, and 1.4 ± 0.2 (massage)	Massage had no significant ($P > 0.05$) effect on muscle strength 96 hours AE, and perceived level of DOMS reduced only at 48 hours AE

TABLE 2. (*continued*) A Summary of 17 Case Series

1st Author	Subject Type	Type of Massage	Outcome Measures	Exercise Magnitude and Frequency	Study Design	Number and Timing of Massage Sessions	Results	Conclusions
Zainuddin Z[7]	Healthy individuals (5 men and 5 women) with no recent arm injury or resistance training	Effleurage, petrissage, and friction rubs	Max isometric torque (MIMT) and peak soreness (PS) in flexion (FE) and extending elbow (EE) before and immediately after exercise (IAE), 30 minutes, and 1, 2, 3, 4, 7, 10, and 14 days after exercise (AE)	10 sets of 6 maximal voluntary contractions of the elbow flexors (at a velocity of 90 degrees·sec^{-1}) separated by 2 weeks	Two-arm comparison model; one arm assigned to massage and the other to control. Subjects performed identical set of exercises (separated by 2 weeks) followed by 1 of the 2 interventions. Subjects in control arm rested for 10 minutes	1 session, 10-minute sports massage applied 3 hours AE	MIMT (Nm) at IAE and 14 days AE = 17.3 ± 3.2 and 23.3 ± 4.5 (control); 17.7 ± 2.9 and 25.4 ± 4.7 (massage). PS (mm), FE occurred day-3 = 42.1 ± 6.5 (control); 25.1 ± 7.5 (massage) and EE occurred day-4 = 52.8 ± 7.0 (control) and 42.9 ± 5.6 (massage). Also, no significance ($P > 0.05$) between control and massage for outcome measures at any other time points	Massage had a significant ($P < 0.05$) effect in alleviating DOMS but not in enhancing muscle function
Gupta S[10]	10 male athletes (5 national walkers, 4 junior middle distance, and 1 junior long distance runner)	Kneading and stroking	Blood lactate concentration (BLa), half-life (time to remove half the amount of lactate in blood), and heart rate (HR) recorded at recovery periods of 0, 3, 5, 10, 20, 30, and 40 minutes for active (AR), passive (PR), and massage (MR) recovery	Bicycle ergometer at 150% VO_2max, for 1-minute intervals with 15-second rest until exhaustion	Subjects underwent all interventions separated by 48 hours. Control treatment subjects rested in relaxed sitting position (40 minutes)	1 session, 10-minute duration; given directly after 1 exercise session (randomly assigned)	BLa half-life (min) = 21.5 ± 2.8 (PR), 15.7 ± 2.5 (AR), and 21.8 ± 3.5 (MR). HR (beats/min) for MR (81 ± 5.3) and PR (79 ± 9.1) decreased at 30th min of recovery but still were significantly ($P < 0.05$) higher than AR (67 ± 5.3)	Massage had no significant effect ($P > 0.05$) in enhancing lactate removal compared to PR
Tanaka T[20]	16 men and 13 women with no history of back pain or major physical illness	Effleurage, kneading, and compression techniques	Mean power frequency (MNF) electromyography (EMG) signal analysis and subjective feeling of fatigue evaluated using VAS during 90 seconds of sustained lumbar muscle contraction after rest (AR) and massage (AM)	Sustained back extension for 90 seconds	Subjects received 1 of the 2 interventions in an alternating fashion after eccentric exercise. Control treatment subjects rested in the prone position (5 minutes)	1 session, 5-minute massage on lumbar region directly after back extension	MNF (Hz) = 1.62 ± 0.48 (AR); 1.65 ± 0.54 (AM). Change in VAS = –0.32 ± 2.34 (AR); 0.86 ± 1.53 (AM)	A significant ($P < 0.05$) difference was observed between massaged and rest condition on VAS but not on EMG

(*continued on next page*)

TABLE 2. (*continued*) A Summary of 17 Case Series

1st Author	Subject Type	Type of Massage	Outcome Measures	Exercise Magnitude and Frequency	Study Design	Number and Timing of Massage Sessions	Results	Conclusions
Rinder AN[11]	13 male and 7 female volunteers screened using standard fitness assessment test	Effleurage and pettrisage	Performance, mean number of leg extensions (MNLE) against a half maximum load. Fatigue-inducing exercise (FIE) followed by rest or massage	Maximum number of leg extensions against a half maximum load until fatigue	Subjects randomly assigned to 1 of the 2 interventions and repeated the procedure with alternate intervention. Control treatment subjects rested in supine position (3 minutes)	First session, 3-minute massage per leg, directly after FIE and a similar second session after a minimum 2-day interval	MNLE after rest = 28 ± 2 (control); 25 ± 2 (rested). MNLE after massage = 31 ± 2 (control); 32 ± 2 (massage)	Massage after exercise fatigue significantly ($P < 0.05$) improved individual MNLE compared to rest
Barlow A[12]	10 healthy and active men with no musculoskeletal disorders	Effleurage and petrissage strokes	Sit and reach (SR) performance before and after therapy	3 attempts at SR tests separated by a 30-second rest in tucked limb position	Subjects randomly assigned to interventions. Control treatment subjects rest in supine position (15 minutes)	1 session, 15-minute massage followed by SR	Change in SR scores (%) for no massage (4.6 ± 4.8) and massage (6.0 ± 4.3) not significantly ($P > 0.05$) different	Massage was not associated with any significant ($P > 0.05$) increase in SR performance
Hemmings B[21]	8 male amateur boxers with minimum of 2 years experience	Effleurage and petrissage	Boxing ergometer output (BEO), peak heart rate (PHR), and perceived recovery ratings (PRR), assessed before, during, and after performances (PF)	80 straight punches per round. Total of 10 rounds (5 rounds per performance)	Counterbalanced with boxers undergoing both interventions (separated by 1 week). Control treatment group underwent supine rest (20 minutes)	1 session, 20-min massage routine immediately after first performance	BEO (N) after first/ second PF = 1239 ± 82/1254 ± 84 (control); 1263 ± 72/ 1288 ± 68 (massage). PHR (beats/ min) after first/second PF = 182 ± 5/185 ± 5 (control); 184 ± 5/187 ± 5 (massage). PRR control (12.1 ± 4.0) significantly lower ($P < 0.05$) than massage (19.0 ± 3.8)	Massage observed to have psychological benefits, but no significant ($P > 0.05$) benefits on boxing performance
Hinds T[4]	13 men with no history of cardiovascular or musculoskeletal disorders	Deep effleurage and petrissage	Femoral artery (FABF), skin (ST), blood lactate (BLa) immediately post rest (IPR) or massage (IPM) compared to baseline	3 × 2-minute bouts of concentric knee extensor exercise at a contraction velocity of 240 degrees·s^{-1}	Counterbalanced with repeated measures, subjects acting as their own control. Control treatment subject rested in semirecumbent position until end of testing	2 × 6-minute massage sessions separated by 1 minute given 1 minute after exercise	FABF (ml·min^{-1}) = 750 ± 150 (IPR); 800 ± 200 (IPM). ST (°C) = 31 ± 1.7 (IPR); 32.5 ± 1.1 (IPM). Bla (mmol·L^{-1}) = 2.36 ± 0.87 (IPR); 2.53 ± 1.17 (IPM). HR (beats/ min) = 77 ± 10 (IPR); 74 ± 14 (IPM)	Post-exercise massage to the quadriceps was not a significantly ($P > 0.05$) effective treatment compared to rest

TABLE 2. (*continued*) A Summary of 17 Case Series

1st Author	Subject Type	Type of Massage	Outcome Measures	Exercise Magnitude and Frequency	Study Design	Number and Timing of Massage Sessions	Results	Conclusions
Robertson A[13]	9 healthy male rugby, football, and hockey athletes	Effleurage	Blood lactate (Bla), mean power (MP), heart rate (HR), and fatigue index (FI) recorded for massage and rest post exercise bouts (PEB)	6 standardized 30-second high-intensity exercise bouts on cycle ergometer	Subjects received either 1 of the 2 interventions assigned in a random crossover fashion. Control treatment subjects had a passive supine rest (20 minutes)	1 session, massage applied after 5 minutes of recovery; 20 minutes in duration	Bla (mmol·L) last PEB = 4.5 ± 0.6 (control); 3.5 ± 0.1 (massage). MP (W) last PEB = 295 ± 12 (control); 305 ± 10 (massage). HR (beats/ min) last PEB = 176 ± 11 (control); 174 ± 8 (massage). FI (%) = 34.2 ± 2.1 (control); 30.2 ± 2.2 (massage)	No significant ($P > 0.05$) measurable physiological effects of leg massage observed. However, lowered FI warrants further investigation
Young R[14]	12 right-handed university-aged men with no history of musculoskeletal injury/disease of the upper limb or hand	Slow, rhythmic, effleurage massage, deep stroking	Dynamometry – F_{max}(isometric) and G_{max}(maximal gradient of force development) in small muscles of hand before fatigue (BF) and after fatigue (AF)	20 thumb contractions followed by 1 minute of sustained isometric contraction against a button	Subjects randomly allocated to 1 of the 2 interventions after 2 similar but separate sessions in an alternating fashion. Control treatment subjects rested in a horizontal position (5 minutes)	1 session, massage applied immediately after exercise (5-minute duration)	F_{max} (N) BF/AF = 57 ± 14/56 ± 14 (rest); 58 ± 15/57 ± 15 (massage). G_{max} (N/s) BF/ AF = 410 ± 115/ 400 ± 125 (rest); 415 ± 110/410 ± 120 (massage)	Massage was not significantly ($P > 0.05$) effective in the restoration of post fatigue F_{max} and G_{max} in small muscles of the hand
Jourkesh M[15]	10 adolescent soccer players aged 15 years (Tabriz, Iran)	Effleurage and petrissage strokes	Sit and reach (SR) scores were evaluated both before and after each treatment session	3 attempts (best one chosen) at SR test separated by a 30 seconds of rest in a tucked limb position	Subjects randomly assigned to 2 different groups. Each group received both treatments separated by 1 week. Control group received supine rest for 15 minutes	1 session, 13-minute massage immediately after SR test	Change in SR scores (%) for subjects with relatively high reach (>15 cm): 3.5 ± 3.7 (no massage) and 5.0 ± 3.2 (massage); subjects with relatively low reach (<15 cm): 14.4 ± 14.1 (no massage) and 17.1 ± 7.1 (massage)	Massage did not significantly ($P > 0.05$) affect SR scores

(*continued on next page*)

TABLE 2. (*continued*) A Summary of 17 Case Series

1[st]Author	Subject Type	Type of Massage	Outcome Measures	Exercise Magnitude and Frequency	Study Design	Number and Timing of Massage Sessions	Results	Conclusions
Sykaras E[16]	12 elite female Tae Kwon Do athletes; mean age, 19	Effleurage, petrissage, superficial warming, and pincement and slapping	Peak concentric (PCT) and eccentric (PET) torque	Continuous concentric/ eccentric isokinetic exercise (6 sets of 10 repetitions, with 2-minute intervals)	Subject's both limbs studied; one limb served as the experimental (by random selection), and the other as the nonmassaged control	Massage sessions during the 2-minute interval between the 6 sets of 10 repetitions	PCT (Nm) for no massage = 93.16 ± 25.12 and massage = 128.08 ± 21.39. PET (Nm) for no massage = 135.58 ± 29.50 and massage = 198.83 ± 28.57	Massage during isokinetic exercise intervals had an enhancing effect on PET of the knee extensors
Barlow A[17]	11 healthy active men participated	Petrissage and effleurage	Electromyography (EMG) was used to record the electrical activity of right biceps femoris. Averaged/ integrated EMG (aEMG) calculated as a gradient of time	30-second knee flexion – intervention – 30-second knee flexion. Knee flexion (5 degrees from full extension)	Crossover, each subject randomly assigned to receive either a massage of the hamstring muscles or a prone rest (control)	1 session immediately after first knee flexion (15 minutes duration)	aEMG for massage: 33.0 ± 25.2 (pre-intervention) and 32.3 ± 24.5 (post-intervention). aEMG for nonmassage: 36.5 ± 34.0 (pre-intervention) and 36.8 ± 35.1 (post-intervention)	A single massage of the hamstring muscles had no significant ($P > 0.05$) effects on EMG of biceps femoris during submaximal isometric contractions
Hunter A[18]	10 healthy male subjects who were physically active on a regular basis volunteered for the study	Stroking, effleurage, petrissage, wringing, and rolling	Changes in mean force (MF) knee extensors at speeds of 60, 120, 180, and 240 degrees/ second. Electromyography (EMG) route mean square (RMS) values normalized as % of maximal voluntary contraction at 60°/s	3 maximal contractions at each of the speeds; 10-second rest between contractions and 1-minute rest between velocities	Subjects randomly received 1 of the 2 interventions. Control group received rest in supine position	1 session for 30 minutes immediately after muscle function testing	MF (N) for no massage: 6 ± 28 at 60 degrees/second; 10 ± 32 at 120 degrees/second; 2 ± 40 at 180 degrees/ second; 3 ± 36 at 240 degrees/ second. MF (N) for massage: 47 ± 25 at 60 degrees/ second; 33 ± 22 at 120 degrees/ second; 16 ± 25 at 180 degrees/ second; 7 ± 30 at 240 degrees/ second. EMG RMS (%) after no massage = 53 ± 15 and massage = 43 ± 15	Change in MF showed a significant decrease ($P < 0.05$) at 60 degrees/ second with massage. However, no corresponding difference seen in the EMG data between massage and passive rest

TABLE 3. A Summary of 10 Randomized Controlled Trials

First Author [Delphi score (x/9)]	Subject Type	Type of Massage	Outcome Measures	Exercise Magnitude and Frequency	Study Design	Number and Timing of Massage Sessions	Results	Conclusions
Brooks C[25][5]	13 male and 39 female university students and faculty with no recent upper body injuries or massage within 1 week of study	Effleurage and circular friction	Power-grip measurements (PGM) after no massage to dominant hand (NMDH) and massage to dominant (MDH) and nondominant hand (MNDH) immediately after exercise (IAE) compared to baseline	3 minutes of maximal exercise with a hand exerciser on both hands that produced fatigue to at least 60% of baseline	Subjects blindly selected 1 of the 4 random intervention groups (13 × 4 groups). Control group rested for 5 minutes	1 session of 5-minute hand massage IAE	PGM (kg) = -1 ± 7.1 (NMDH), 2.2 ± 3.8 (MDH), and 3.1 ± 3.7 (MNDH)	Massage IAE had a significantly ($P < 0.05$) greater effect than nonmassage on immediate grip performance after fatigue
Rodenburg JB[30][2]	50 male subjects with no active participations in sports activities requiring a lot of arm power	Muscles pressed and shaken, skin manipulated, effleurage, tapotement, petrissage	Flexion (FAE) and extension (EAE) angle of elbow, and DOMS before and after exercise (AE)	120 forced contractions of forearm around elbow (45 to 170 degrees flexion) extensions in 30 minutes	Subjects assigned randomly to the control group (n = 27) or the treatment group (n = 23). Control group rested until the end of testing	1 session, 15 minutes AE and pre-DOMS: coupled with warm-up and stretching	FAE/EAE (degree) 1 and 96 hours AE = 42 ± 1/147 ± 1.4 and 38 ± 0.4/148 ± 1.3 (control); 38 ± 0.2/150 ± 1.3 and 36 ± 0.1/151 ± 1.1 (massage). DOMS 1 and 96 hours AE = 0.5 and 2 (control); 0 and 1.2 (massage)	Warm-up, stretching, and massage significantly ($P < 0.05$) enhanced FAE and lessened DOMS AE, but not EAE
Lane K[27][2]	10 physically active male volunteers with no prior serious medical illness	Deep effleurage, compressions, deep muscle stripping, jostling, cross-fiber frictions	Cycle ergometer output (CEO) between 2 identical, intermittent sessions separated by 24 hours. Massage (MS), active recovery (AR) or cold water immersion (CWI) treatments	18 minutes of cycling performed in succession (resistance of 80 g/kg body wt.) separated by 24 hours	All subjects assigned to 1 of 4 recovery conditions in a randomized counterbalanced order. Control group sat passively for 15 minutes (same time as the interventions)	1 session immediately after first intermittent cycling session; 15-minute duration	Only the control group = 77 ± 11% had a significant ($P < 0.05$) decline in CEO between first and second session compared to MS =37 ± 26; AR = 14 ± 27; CWI = -10 ± 19	MS, AR, and CWI appeared to show significantly ($P < 0.05$) less decline in work output compared to rest

(*continued on next page*)

TABLE 3. (*continued*) A Summary of 10 Randomized Controlled Trials

First Author [Delphi score (x/9)]	Subject Type	Type of Massage	Outcome Measures	Exercise Magnitude and Frequency	Study Design	Number and Timing of Massage Sessions	Results	Conclusions
Smith LL[5][3]	10 healthy, active, and untrained male subjects with no prior major medical conditions	Effleurage, shaking, petrissage, wringing, cross-fiber massage	Peak value (PV) for DOMS and CK levels assessed before and at 8, 24, 48, 72, 96, and 120 hours after exercise (AE)	20 submaximal concentric contractions at 120 degrees/second up to 90 degrees followed by 5 maximal concentric contractions	Randomly assigned to massage (n = 7) or control (n = 7) group. Control group remained in supine position with exercised arm immobile for 30 minutes (same amount of time as massage)	1 session; 2 hours post-exercise; 30-minute duration	DOMS in control significantly ($P < 0.05$) higher than massage from 24 to 96 hours and PV control = 5.9 ± 0.5 at 48 hours; PV massage = 4.6 ± 0.7 at 24 hours. CK (U/L) in control significantly ($P < 0.05$) higher than massage from 8 to 120 hours and PV control = 1917 ± 1023 at 96 hours; PV massage = 1083 ± 476 at 120 hours	Sports massage significantly ($P < 0.05$) reduced CK levels and symptoms of DOMS when used 2 hours AE
Mancinelli C[33][3]	22 NCAA Division I female basketball and volleyball players	Effleurage, petrissage, and vibration	Vertical jump displacement (VJD) and delayed-onset muscle soreness (DOMS) using visual analog scale (VAS) immediately after exercise (IAE)	Endurance training and upper/lower extremity resistive exercises 3 consecutive days	A randomized pre-test and post-test control group design. Subjects in control group rested for 17 minutes	1 session; 17-minute duration after recording outcome measures, day 4 IAE	VJD (cm) no massage = 45.8 ± 4.7 (pre-test) and 46.2 ± 3.1 (post-test); massage = 49.9 ± 5.7 (pre-test) and 48.1 ± 5.1 (post- test). DOMS no massage = 5 ± 2 (pre-test) and 5 ± 3 (post test); massage = 5 ± 1 (pre-test) and 3 ± 1 (post-test)	Massage in women collegiate athletic training significantly ($P < 0.05$) improved VJD and decreased DOMS

TABLE 3. (*continued*) A Summary of 10 Randomized Controlled Trials

First Author [Delphi score (x/9)]	Subject Type	Type of Massage	Outcome Measures	Exercise Magnitude and Frequency	Study Design	Number and Timing of Massage Sessions	Results	Conclusions
Hilbert JE[29][4]	18 male and female volunteers with no recent knee injuries, weight training, or antiinflammatory medication in last 4 months	Classical Swedish techniques: effleurage, tapotement, petrissage	Assessment of peak torque (PT) immediately (IAE) and at 2, 6, 24, and 48 hours after exercise (AE); range of motion (ROM) and intensity of soreness (IS) at 6, 24, and 48 hours AE	6 sets of 10 maximal eccentric contractions with the right hamstring with 1-minute rest	Subjects randomly assigned to either massage (n = 9) or a nonmassaged control group (n = 9). Control group rested for 20 minutes	1 session; 20-minute duration given 2 hours AE	PT (Nm) IAE and 48 hours AE = 134.3 ± 43.1 and 120.9 ± 44.8 (control); 120.3 ± 38.2 and 115.8 ± 38.2 (massage). ROM (degrees) 6 and 48 hours AE = 78.3 ± 10.3 and 69.0 ± 10.6 (control); 84.8 ± 12.8 and 79.7 ± 14.0 (massage). IS 6 and 48 hours AE = 6 ± 3 and 14 ± 3 (control); 7 ± 3 and 10 ± 3 (massage)	Massage AE did not significantly ($P > 0.05$) improve hamstring function, but it did reduce IS 48 hours AE
Dawson L[32][3]	Healthy recreational runners (8 men and 4 women) from St. John's Marathon, ON, Canada	Effleurage with flushing, petrissage (deep strokes), and stretching	Quadriceps peak torque (PT) of body weight (BW), leg swelling (LS), and soreness perception (SP) at baseline and post-race days (PRD)	Completed a half marathon (21.1 km). Participants ran on an average of 35.0 ± 11.7 km·week^{-1}	All participants had 1 leg randomly massaged after marathon. Nonmassaged leg served as the control	Massage sessions 30 minutes in duration post race on days 1, 4, 8, and 11	PT (Nm.Kg BW^{-1}) PRD 1 and 11 = 21 ± 4.5 and 22 ± 4.0 (control); 21 ± 4.5 and 22 ± 3.5 (massage). LS (cm) PRD 1 and 11 = 48 ± 2 and 47 ± 1 (control); 49 ± 2 and 47.5 ± 1 (massage). SP PRD 1 and 11 = 2.4 ± 1.2 and 0.9 (control); 2.6 ± 1.2 and 0.9 (massage)	Massage had no significant ($P > 0.05$) physiological or psychological benefits

(*continued on next page*)

TABLE 3. (*continued*) A Summary of 10 Randomized Controlled Trials

First Author [Delphi score (x/9)]	Subject Type	Type of Massage	Outcome Measures	Exercise Magnitude and Frequency	Study Design	Number and Timing of Massage Sessions	Results	Conclusions
Weber MD[31][3]	40 healthy and untrained females from the local community and university in Jackson, Mississippi	Effleurage leading to petrissage followed by quick effleurage	Muscle soreness rating using VAS and peak torque (PT) at 60 degrees/second measured 24 and 48 hours after exercise (AE) for electrical stimulation (ES), upper body ergometry (UBE), and massge therapy (MT)	Sets of 10 repetitions followed by 1- minute rest until exhaustion	Subjects randomly assigned to 1 of the 4 intervention group (n = 10 each group). Control group rested for 8 minutes (same amount of time as the interventions)	1 session, 8-minute full body massage immediately AE	VAS 24 and 48 hours AE = 1.0 ± 2.0 and 1.5 ± 1.5 (control); 1.5 ± 1.5 and 3.0 ± 1.5 (ES); 1.0 ± 2.0 and 1.5 ± 1.5 (UBE); 1.0 ± 1.5 and 2.0 ± 1.5 (MT). PT 24 and 48 hours = 17.4 ± 2.3 and 16.1 ± 3.9 (control); 16.0 ± 3.0 and 17.1 ± 3.1 (ES); 16.1 ± 4.6 and 17.5 ± 5.2 (UBE); 19.1 ± 4.7 and 19.7 ± 5.3 (MT)	No significant differences ($P > 0.05$) between MT, ES, UBE, and control groups in PT or VAS rating
Martin NA[26][6]	10 male competitive cyclists from Panther Cycling Club, Pittsburgh, Pennsylvania	Sports massage consisting of effleurage, petrissage, tapotement, and compressions	Venous blood lactate concentration (BLa) for each test condition: active recovery (AR), sports massage (SM), or rest (RE) treatments after exercise (AE)	80 revolutions/minute for 3 minutes at a brake force of 1 kg (ramped up 1 kg for second stage, and 0.5 kg for remaining stages	Counterbalanced with repeated measures under 3 experimental conditions (subjects participated in all 3 conditions). Subjects in control condition rested 20 minutes	1 session, 5-minute massage to each leg in the supine and prone positions immediately AE	Bla (mmol/L) 5 min AE = 11.0 ± 2.5 (AR); 12.5 ± 1.8 (SM); 11.0 ± 1.8 (RE). Bla (mmol/L) 15 min AE = 8.0 ± 2.1 (AR); 10.6 ± 2.0 (SM); 9.4 ± 2.2 (RE). Bla (mmol/L) 25 min AE = 4.5 ± 1.4 (AR); 7.9 ± 1.8 (SM); 7.0 ± 1.9 (RE)	No significant ($P > 0.05$) difference was found between massage and rest for changes in BLa
Monedero J[28][3]	18 trained male cyclist tested preseason competition in Dublin, Ireland	Effleurage, stroking, and taponement	Blood lactate (BLa) removal rate after active (AR), passive (PR), massage (MR), and combined (CR, active + massage) recovery	6 cycling sessions of varying intensity and duration on a King Cycle Tester unit	Intervention sequences (15 minutes) were randomized across cyclists. Control subjects rested (PR) on chair for 15 minutes	1 session, 15-minute massage immediately after cycling performance	BLa ($mmol{\cdot}min^{-1}$) = 0.37 ± 0.03 (AR); 0.38 ± 0.04 (CR); 0.21 ± 0.04 (MR); 0.16 ± 0.06 (PR)	MR was not significantly ($P < 0.05$) more effective than PR for BLa removal

by Dawson et al demonstrated that a 30-minute massage immediately after a marathon had no effect on quadriceps peak torque output, muscle soreness, and leg circumference.[32] However, the Mancinelli et al findings support the use of a 17-minute massage after intense training sessions in women collegiate athletes to reduce DOMS and improve vertical jump performance.[33]

DISCUSSION

Our original goal was to complete a meta-analysis to answer the question, "Does massage aid recovery of muscle function after intense exercise?" This was not possible given that the studies varied tremendously in their use of massage type and massage condition (number of times, duration, magnitude, and rate). We therefore conducted a systematic review examining multiple outcome measures for the efficacy of massage including range of motion and recovery of joint torque for performance, lactate removal and blood flow for physiological effects, and muscle pain for assessing the effectiveness of massage on post-exercise recovery.

The potential to expedite post-exercise recovery using massage has garnered great interest from traditional medicine disciplines such as sports medicine. A common feature of many of the studies reported herein is that a single massage session was administered after exercise. Furthermore, only the limb or body part that was exercised received massage. It is possible therefore that multiple massage sessions could lead to different results. Furthermore, the application of massage to more than just the exercised limb is another possible strategy that could be employed.

All studies included in this systematic review used different combinations of 2 parameters: time of treatment after exercise and duration of treatment. In addition, different massage techniques (eg, effleurge, petrissage) were used. Moreover, there was no report of the amount of force applied by the practitioner in any of the studies. The relationship between force magnitude, duration, and frequency of massage is not well understood and could perhaps be systematically evaluated through the use of appropriate animal models to better understand the relationship between these variables.

The majority of case series in this review used subjects as their own controls. This approach reduces the chance for confounding variables such as individual differences in response to massage or rest (control). However, using a within-subjects design alone could result in effects that might be explained otherwise by spontaneous recovery, a placebo effect or statistical regression to the mean. Several RCTs addressed this issue by having additional treatment groups thereby further strengthening the findings that massage alone explained the beneficial effects observed.[26-28,31]

The beneficial effects of massage on muscle recovery were best realized when the treatment was administered within 2 hours of exercise.[5,11,25,28-30,33] No similar correlations were found between timing or duration of the massage and muscle recovery benefits.

The review included 3 studies where the massage protocol was significantly different. In 1 study, massage was administered before exercise, yielding no improvement in subsequent functional performance.[12] In 1 study, a combined recovery of massage and active recovery was more effective than massage alone in improving physiological measures.[28] Similarly, in another study, massage was performed in combination with warm-up and stretching.[30] The authors noted a strong benefit of this protocol, suggesting that massage alone may not be an optimal strategy for improving muscle function after intense exercise.

This systematic review identified that contraindications for massage therapy (skin conditions, sensitivity to touch) and effective massage techniques have not been addressed in the literature.

CONCLUSIONS

This evidence-based review demonstrated that RCTs provided stronger overall evidence than case series for the effectiveness of massage in promoting muscle recovery and alleviating DOMS after exercise. The need for further research and the standardization of massage therapy techniques and their application is apparent from this review of the current literature. Such studies could provide the basis for a meta-analysis and more definitive conclusions on the efficacy of massage therapy and its role in promoting recovery after intense exercise.

REFERENCES

1. Galloway S, Watt J, Sharp C. Massage provision by physiotherapists at major athletic events between 1987 and 1998. *Br J Sport Med*. 2004;38: 235–237.
2. Cafarelli E, Flint F. The role of massage in preparation for and recovery from exercise. *Sports Med*. 1992;14:1–9.
3. Weerapong P, Hume PA, Kolt GS. The mechanisms of massage and effects on performance, muscle recovery and injury prevention. *Sports Med*. 2005;35:235–56.
4. Hinds T, McEwan I, Perkes J, et al. Effects of massage on limb and skin blood flow after quadriceps exercise. *Med Sci Sports Exerc*. 2004;36: 1308–1313.
5. Smith LL, Keating MN, Holbert D, et al. The effects of athletic massage on delayed onset muscle soreness, creatine kinase, and neutrophil count: a preliminary report. *J Orthop Sports Phys Ther*. 1994;19:93–99.
6. Moraska A. Therapist education impacts the massage effect on postrace muscle recovery. *Med Sci Sports Exer*. 2007;39:34–37.
7. Zainuddin Z, Newton M, Sacco P, et al. Effects of massage on delayed-onset muscle soreness, swelling, and recovery of muscle function. *J Athl Train*. 2005;40:174–180.
8. Cheung K, Hume P, Maxwell L. Delayed onset muscle soreness: treatment strategies and performance factors. *Sports Med*. 2003;33:145–164.
9. Verhagen AP, de Vet HCW, de Bie RA, et al. The Delphi list: a criteria list for quality assessment of randomised clinical trials for conducting systematic reviews developed by Delphi consensus. *J Clin Epidemiol*. 1998;51:1235–1241.
10. Gupta S, Goswami A, Sadhukhan AK, et al. Comparative study of lactate removal in short term massage of extremities, active recovery and a passive recovery period after supramaximal exercise sessions. *Int J Sports Med*. 1996;17:106–110.
11. Rinder AN, Sutherland CJ. An investigation of the effects of massage on quadriceps performance after exercise fatigue. *Complement Ther Nurs Midwifery*. 1995;1:99–102.
12. Barlow A, Clarke R, Johnson N, et al. Effect of massage of the hamstring muscle group on performance of the sit and reach test. *Br J Sports Med*. 2004;38:349–351.
13. Robertson A, Watt JM, Galloway SD. Effects of leg massage on recovery from high intensity cycling exercise. *Br J Sports Med*. 2004;38:173–176.

14. Young R, Gutnik B, Moran RW, et al. The effect of effleurage massage in recovery from fatigue in the adductor muscles of the thumb. *J Manipulative Physiol Ther*. 2005;28:696–701.
15. Jourkesh M. The effect of massage on performance of the sit and reach test in adolescent soccer players. *Medicina dello Sport*. 2007;60:151–155.
16. Sykaras E, Mylonas A, Malliaropoulos N, et al. Manual massage effect in knee extensors peak torque during short-term intense continuous concentric-eccentric isokinetic exercise in female elite athletes. *Isokinetics and Exercise Science*. 2003;11:153–157,
17. Barlow A, Clarke R, Johnson N, et al. Effect of massage of the hamstring muscles on selected electromyographic characteristics of biceps femoris during sub-maximal isometric contraction. *Int J Sports Med*. 2007;28: 253–256.
18. Hunter AM, Watt JM, Watt V, et al. Effect of lower limb massage on electromyography and force production of the knee extensors. *Br J Sports Med*. 2006;40:114–118.
19. Farr T, Nottle C, Nosaka K, et al. The effects of therapeutic massage on delayed onset muscle soreness and muscle function following downhill walking. *J Sci Med Sports*. 2002;5:297–306.
20. Tanaka TH, Leisman G, Mori H, et al. The effect of massage on localized lumbar muscle fatigue. *BMC Complement Altern Med*. 2002;2:1–9.
21. Hemmings B, Smith M, Graydon J, et al. Effects of massage on physiological restoration, perceived recovery, and repeated sports performance. *Br J Sports Med*. 2000;34:109–114.
22. Hart JM, Swanik CB, Tierney RT. Effects of sport massage on limb girth and discomfort associated with eccentric exercise. *J Athl Train*. 2005;40: 181–185.
23. Jönhagen S, Ackermann P, Eriksson T, et al. Sports massage after eccentric exercise. *Am J Sports Med*. 2004;32:1499–1503.
24. Tiidus PM, Shoemaker JK. Effleurage massage, muscle blood flow and long-term post-exercise strength recovery. *Int J Sports Med*. 1995;16: 478–483.
25. Brooks CP, Woodruff LD, Wright LL, et al. The immediate effects of manual massage on power-grip performance after maximal exercise in healthy adults. *J Altern Complement Med*. 2005;11:1093–1101.
26. Martin NA, Zoeller RF, Robertson RJ, et al. The comparative effects of sports massage, active recovery, and rest in promoting blood lactate clearance after supramaximal leg exercise. *J Athl Train*. 1998; 33:30–35.
27. Lane KN, Wenger HA. Effect of selected recovery conditions on performance of repeated bouts of intermittent cycling separated by 24 hours. *J Strength Cond Res*. 2004;18:855–860.
28. Monedero J, Donne B. Effect of recovery interventions on lactate removal and subsequent performance. *Int J Sports Med*. 2000;21:593–597.
29. Hilbert JE, Sforzo GA, Swensen T. The effects of massage on delayed onset muscle soreness. *Brit J Sports Med*. 2003;37:72–75.
30. Rodenburg JB, Steenbeek D, Schiereck P, et al. Warm-up, stretching and massage diminish harmful effects of eccentric exercise. *Int J Sports Med*. 1994;15:414–419.
31. Weber MD, Servedio FJ, Woodall WR. The effects of three modalities on delayed onset muscle soreness. *J Orthop Sports Phys Ther*. 1994;20: 236–242.
32. Dawson L, Dawson K, Tiidus PM. Evaluating the influence of massage on leg strength, swelling, and pain following a half-marathon. *J Sports Sci Med*. 2004;3:37–43.
33. Mancinelli CA, Davis DS, Aboulhosn L, et al. The effects of massage on delayed onset muscle soreness and physical performance in female collegiate athletes. *Phys Ther in Sport*. 2006;7:5–13.

