Effects of Massage on Limb and Skin Blood Flow after Quadriceps Exercise

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ABSTRACT

HINDS, T., I. MCEWAN, J. PERKES, E. DAWSON, D. BALL, and K. GEORGE. Effects of Massage on Limb and Skin Blood Flow after Quadriceps Exercise. *Med. Sci. Sports Exerc.*, Vol. 36, No. 8, pp. 1308–1313, 2004. **Purpose:** At present, there is little scientific evidence that postexercise manual massage has any effect on the factors associated with the recovery process. The purpose of this study was to compare the effects of massage against a resting control condition upon femoral artery blood flow (FABF), skin blood flow (SKBF), skin (SKT), and muscle (MT) temperature after dynamic quadriceps exercise. **Methods:** Thirteen male volunteers participated in 3 × 2-min bouts of concentric quadriceps exercise followed by 2 × 6-min bouts of deep effleurage and pétrissage massage or a control (rest) period of similar duration in a counterbalanced fashion. Measures of FABF, SKBF, SKT, MT, blood lactate concentration (BLa), heart rate (HR), and blood pressure (BP) were taken at baseline, immediately after exercise, as well as at the midpoint and end of the massage/rest periods. Data were analyzed by two-way ANOVA. **Results:** Significant main effects were found for all variables over time due to effects of exercise. Massage to the quadriceps did not significantly elevate FABF (end-massage 760 ± 256 vs end-control 733 ± 161 mL·min^{-1}), MT, BL, HR, and BP over control values ($P > 0.05$). SKBF (end-massage 150 ± 49 vs end control 6 ± 4 au) SKT (end-massage 32.2 ± 0.9 vs end-control 31.1 ± 1.3°C) were elevated after the application of massage compared with the control trial ($P < 0.05$). **Conclusion:** From these data it is proposed that without an increase in arterial blood flow, any increase in SKBF is potentially diverting flow away from recovering muscle. Such a response would question the efficacy of massage as an aid to recovery in postexercise settings. **Key Words:** DOPPLER ULTRASOUND, LASER DOPPLER, FEMORAL ARTERY, SKIN AND MUSCLE TEMPERATURE

Despite little scientific evidence to support the therapeutic use of postexercise massage (5), it is generally assumed by athletes and therapists alike that massage can enhance muscle recovery and reduce soreness after intense physical activity (3,4,24). Although it is not known how massage may be able to physiologically affect the temporal aspects or degree of postexercise recovery, it has been postulated that massage may enhance muscle blood flow (8). By increasing blood flow, oxygen delivery to the tissue will increase, therefore enhancing healing, metabolite removal, and a return to homeostasis (2).

Empirical data are, however, equivocal. Wakim et al. (27) reported that blood flow increased by 50% after vigorous massage; however, later studies reported much smaller increases (6,11,13) or no increase at all (7). In these studies, venous occlusion plethysmography was used, and it is known that motion artifacts from massage can prevent accurate data capture. Furthermore, as changes in blood flow are inferred from changes in limb circumference, it is difficult to distinguish between muscle and skin blood flow (SKBF). More recent studies have employed Doppler ultrasound (22,25) and have suggested that massage has little effect on arterial flow. However, like plethysmography, Doppler analysis of single artery blood flow cannot differentiate between the destination of arterial flow, that is, muscle and/or skin.

Increases in SKBF provide no nutritive benefit to the muscle in postexercise conditions. Given that a well-recognized consequence of massage is an increase in skin "rubor" suggestive of elevated SKBF, a limitation in previous studies is the lack of an attempt to simultaneously assess arterial flow and SKBF. If massage does not increase arterial blood flow but there is an elevation in SKBF, it would be plausible that blood flow is re-routed from skeletal muscle and thus may hinder the recovery process.

Concomitant to the use of both Doppler ultrasound and laser Doppler flowmetry to integrate femoral artery blood flow (FABF) and SKBF, this study will uniquely assess skin (SKT) and muscle temperature (MT). Although massage produces heat as a result of friction (3), there are no data reporting changes in surface or underlying tissue temperature consequent to massage application. If vigorous massage can produce changes in the temperature of muscle tissue as

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well as the skin, this may provide another stimulus for metabolic recovery. Therefore, this unique combination of methods and variables should provide a greater insight into the physiological and metabolic effects of massage.

METHODS

Subjects. Thirteen healthy male volunteers with mean (±SD), age 21.0 (1.4) yr, height 1.78 (0.66) m, and mass 78.8 (11.8) kg participated in this study. Written informed consent was gained, and a pretest medical screening questionnaire was completed. Subjects were excluded from the study if they had a history of cardiovascular disease, lower-limb musculoskeletal disorders, or allergies to lignocaine. Ethical approval was gained from Manchester Metropolitan University.

An *a priori* sample size estimation was limited by the lack of any relevant laser Doppler effect size data from previous massage research. Calculating the power for sample number would be based on Doppler measurement as this was the variable most likely to alter in this study based on the previous findings for arterial flow.

Experimental design. A repeated measures design was adopted to assess the impact of massage or control (rest) upon postexercise hemodynamics, skin and muscle temperatures, as well as blood lactate concentration. In both conditions subjects were provided with 10 min of rest before exercise. Measurements of blood flow, muscle temperature, blood lactate, and blood pressure were taken before exercise, immediately postexercise, and at the middle and end of the recovery (massage or rest) period. Treatments were counterbalanced between subjects with each subject acting as their own control. Each testing session was separated by at least 4 d, and the time of day was controlled within subjects. Subjects were requested to repeat their routine of eating, drinking, and activity for the day before both testing sessions.

Procedures. Ambient temperature and relative humidity were recorded at the beginning of each trial. Subjects assumed a semirecumbent position (120° of hip flexion) on an isokinetic dynamometer (Lido, Loredan, Davies, CA) and rested for 10 min to allow for cardiovascular variables to stabilize. At this point, hair on the subjects' thighs was shaved to avoid massage-related irritation of hair follicles and to increase the ease of skin contact of both the skin temperature and laser Doppler flow probes. Local anesthesia was used to reduce the subject discomfort during the repeated measurement of muscle temperature. At the beginning of the rest period, lignocaine (1 mL) 1% was injected around a point 5 cm lateral to a point on the mid-line of the thigh half way between the anterior superior iliac spine and the tibial tuberosity.

Initial resting measurements were performed as follows:

Femoral artery blood flow. FABF was obtained using an Esaote Biomedica AU4 Idea Ultrasound Doppler system (Esoate Biomedica Ltd., Florence, Italy). The femoral artery insonation site chosen was 1–2 cm distal to the inguinal crease. Care was given to avoid imaging the femoral artery too far below the inguinal crease due to arterial branching. This position was marked on the subject's skin for ultrasound head repositioning, thus decreasing the error of site relocation (17). The muscular wall of the artery and high blood pressure allowed positioning of the transducer without deformation of its circular shape (22). The femoral artery was then imaged with a 10.0-MHz transducer at an angle as parallel as possible to flow (inherent angle corrections were made). From the longitudinal image of the femoral artery (along the central path of the ultrasound beam where optimal spatial resolution occurs) systolic and diastolic diameters of the femoral artery were determined to allow the calculation of an average (systolic [1/3] and diastolic [2/3]) cross-sectional area (CSA = $\pi \cdot r^2$) (17). Rädegran (17) reported that femoral artery CSA was reproducible with a mean coefficient of variation of 1.2%, whether the probe was fixed or repositioned. Doppler interrogation of femoral artery flow (sample volume adjusted to the width of the artery) allowed the determination of flow velocity integrals (FVI) for each beat by tracing the outline of the Doppler spectrum.

Skin blood flow. Laser Doppler flowmetry provides continuous real-time qualitative measurement of cutaneous microvascular blood flow (14,18). An estimate of SKBF was obtained via a Perimed Periflux 4001 Master Multichannel Laser Doppler system (Perimed Ltd., Järfälla, Sweden). Previous laser Doppler flow studies have shown that the maximum depth of penetration of the signal ranges from 1 mm (23) to 0.4 mm (26). Thus, the derived results will be purely based at the cutaneous or skin level and would be unaffected by deeper underlying muscle (21). The laser Doppler power spectrum density operates in a frequency range of 0–8.2 Hz representative of the skin blood flow (15). Two skin probes were employed in this study. Both were placed on the anterior aspect of the subject's right thigh. Site 1 was placed at the mid line of the thigh half way between the anterior superior iliac spine and the tibial tuberosity. Site 2 was placed 5 cm distal to the site of lignocaine injection and hence muscle thermistor insertion. At both sites the probes were placed in areas where visually noted blood vessels were absent in order to obtain SKBF from cutaneous capillaries rather than major vessel readings. Such precise positioning allowed reproduction of the site both within and between trials

Skin temperature. SKT was measured using thermocouples attached to a Grant-Squirrel Meter/Logger (type SQ8-16U, range 25–50°C) at two sites immediately distal to the laser-Doppler probes.

Muscle temperature. MT was measured under local anesthesia using a needle thermocouple (Ellab, Roedovre, Denmark) and was inserted into the vastus lateralis muscle to a maximum depth of 3 cm. Muscle temperature was recorded at depths of 3, 2, and 1 cm. The skin was cleaned with an alcohol swab before each temperature measurement. The same insertion site was used both within and between trials.

Blood lactate concentration. Capillary blood samples (50 μL) were obtained from the fingertip and were

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analyzed, in duplicate, for the concentration of lactate using a YSI (1500) Sport L-Lactate analyzer (Yellow Springs Instruments, Yellow Springs, OH).

Blood pressure and heart rate. BP was measured using a standard mercury sphygmomanometer and a stethoscope. Heart rate was obtained using ECG integral to the ultrasound system.

Each subject completed an exercise test protocol in both trials, which consisted of three 2-min bouts (30-s rest in-between bouts) of concentric knee extensor exercise at a contraction velocity of $240°\cdot s^{-1}$ using a Lidoactive isokinetic dynamometer (Loredan Biomedical, West Sacramento, CA). Maximal voluntary extension torque for each concentric quadriceps contraction was generated with passive flexion provided by an experimenter to minimize hamstring activity. Subjects were verbally motivated to perform 60 maximal repetitions within each 2-min time period. Total work was recorded for each 2-min exercise bout in order to match the work done during subsequent repeat testing. Subjects were fully familiarized with the exercise protocol before testing. Toward the end of the third bout of knee extensor exercise, the Doppler transducer was repositioned over the femoral artery so that blood flow could be estimated over the first five beats of recovery. During the first 60 s after exercise the subject relaxed while immediate postexercise measurements of SKBF, SKT, MT, BLa, BP, and HR were ascertained. At exactly 1 min postexercise, subjects then began either a massage protocol or a rest protocol. For 60 s in the middle of the massage/rest and for 1 min at the end of the massage/rest, measures of all dependent variables were taken.

The massage protocol was deep massage applied to the exercised quadriceps muscle mass. This consisted of a combination of deep effleurage and pétrissage. Two 6-min bouts of massage were applied, separated by a 1-min rest. The same chartered physiotherapist was used in order to control the application and the amount of pressure directed to the quadriceps musculature. Stroke rate was 60 min^{-1} for effleurage and 50–60 min^{-1} for pétrissage. Effleurage massage consisted of rhythmic pressures along the longitudinal axis of the muscle group. Pétrissage consisted of kneading and squeezing motions over the muscle mass. The two massage techniques were alternated every 30 s. The massage protocol was chosen to represent a commonly used postevent recovery massage and is similar to techniques used in previous massage research (5,22,25). Hypoallergenic skin oil (The Boots Company PLC, Nottingham, UK) was used to reduce friction between the therapist's hands and the subject's skin. The control treatment subjects refrained from activity immediately after the exercise and remained resting in the semirecumbent position until completion of the test. This position was controlled between trials.

Statistics. Data were analyzed using Statistica (StatSoft, Tulsa, OK) software. A critical alpha of 0.05 was selected. Data for ambient temperature and relative humidity were analyzed by repeated measures *t*-test. Work for each of three exercise bouts in two trials and physiological data between trials and over time were analyzed by two-way ANOVA with repeated measures. A Tukey *post hoc* test was used to determine exactly where significant differences occurred if *F*-ratios were significant. All data reported in the results are mean (±SD).

RESULTS

Laboratory temperature (21.5 ± 1.1 vs 21.7 ± 1.5°C) and relative humidity (46.1 ± 3.6 vs 43.9 ± 4.4%) were relatively constant between the massage and control trials, respectively ($P > 0.05$). There was a significant drop in work completed during exercise bout 1 to bout 3 ($P < 0.05$) in both trials. However, the work completed was similar between trials for all three exercise bouts (massage: 6115 ± 729, 5128 ± 922, and 5018 ± 889; control: 6214 ± 897, 5213 ± 833, and 4961 ± 828 W; $P > 0.05$). Also the mean total work completed was similar between trials (massage: 5420 ± 966 W; control: 5462 ± 994 W; $P > 0.05$).

Femoral artery blood flow (see Fig. 1) increased from rest to postexercise in both trials ($P < 0.05$). After this increase, due to the demands of the exercise, FABF returned toward baseline in both trials in a progressive fashion. There were no significant differences in FABF between trials during or after the massage/rest.

Skin blood flow data were similar at both sites in each respective trial, and thus the average SKBF data are presented in Figure 2. Resting SKBF was similar between trials and increased significantly with exercise in both trials ($P > 0.05$). With massage SKBF was further ($P < 0.05$) elevated in the massage trail whereas SKBF in the control trial returned to baseline levels.

Skin temperature responses were similar at both sites in each respective trial, and thus the average SKT data are presented in Figure 3. Skin temperature increased in both trials from pre- to postexercise ($P < 0.05$). During the postexercise rest period, the SKT continued to increase for the massage trial but remained stable in the control trial. A significant interaction for time/treatment was observed in

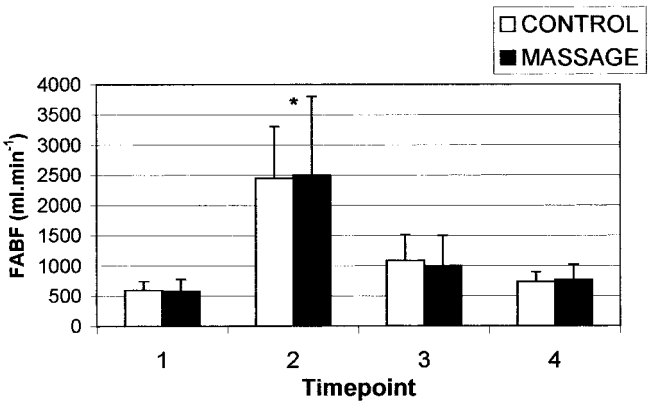

FIGURE 1—Femoral artery blood flow during the massage and control trials. Time point 1, preexercise; time point 2, immediately postexercise; time point 3, mid massage/rest; time point 4, immediately postmassage/rest; * significantly different from baseline; # significantly different between trials.

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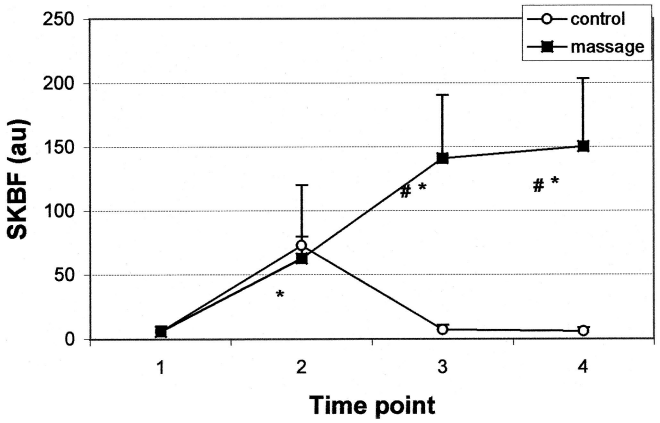

FIGURE 2—Skin blood flow during the massage and control trials.

the ANOVA ($P < 0.05$), suggesting a different response in skin temperature between trials over the duration of experimental manipulation.

At rest there was an MT gradient of ~2°C across the 1–3 cm depth of test sites and this was maintained throughout testing. As MT responses were similar at all depths in each respective trial, the average MT data are presented in Table 1. Muscle temperature increased by an average of 2.5°C from rest to postexercise ($P < 0.05$) in both trials. Likewise, the temperature decrease postexercise in the massage and control trials was similar ($P > 0.05$). All temperatures remained elevated at the cessation of treatment when compared with baseline levels.

Blood lactate concentration increased significantly from rest to postexercise in both trials (massage, 0.91 ± 0.33 to 4.11 ± 1.13; control, 0.92 ± 0.25 to 4.05 ± 1.16 $mmol \cdot L^{-1}$). Although lactate levels returned toward baseline at the end of each trial (massage: 2.53 ± 1.17; control: 2.36 ± 0.87 $mmol \cdot L^{-1}$), these values were still significantly elevated over resting data. There were no between trial differences at any time point.

Significant increases in HR (massage: 66 ± 12 to 123 ± 19; control: 63 ± 8 to 121 ± 15 $beats \cdot min^{-1}$) and systolic BP (massage: 124 ± 10 to 142 ± 7; control: 129 ± 6 to 141 ± 9 mm Hg) occurred at the postexercise measurement

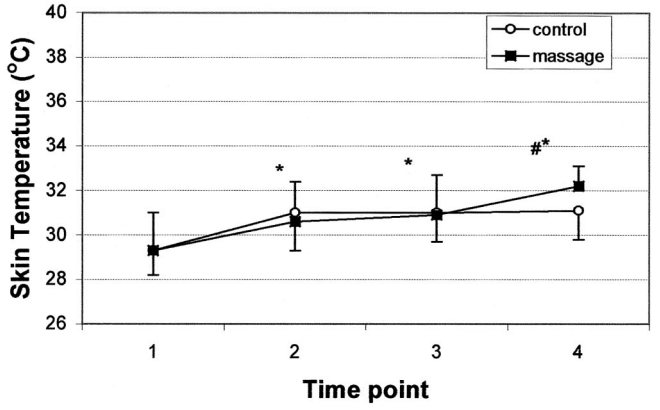

FIGURE 3—Mean skin temperature during the massage and control trials.

TABLE 1. Change in muscle temperature (°C) from baseline at 1-, 2-, and 3-cm depths before and after exercise during massage and control trials.

Condition	Preexercise (Baseline)	Postexercise (min)		
		0	6	12
Control 1 cm	33.9	2.2	2.1	1.7
Control 2 cm	34.7	2.8	2.3	1.5
Control 3 cm	35.6	2.4	1.8	1.4
Massage 1 cm	33.8	2.8	2.4	2.1
Massage 2 cm	34.8	3.1	2.2	1.9
Massage 3 cm	35.7	2.5	1.7	1.4

point compared with rest ($P < 0.05$) for both trials. Both HR (massage: 78 ± 14; control: 77 ± 10 $beats \cdot min^{-1}$) and BP (massage: 126 ± 8; control: 126 ± 8 mm Hg) returned toward baseline levels at the end of each trial. No significant between trial differences in HR and BP were detected.

DISCUSSION

During athletic events the ability to recover from the effects of exercise is vital and postevent massage is often applied to athletes in the belief that it will overcome fatigue and aid in muscle recovery (1), and it has been postulated that various types of massage may enhance muscle blood flow (16).

The key finding of this study is that massage did not affect FABF. This supports the work of Tiidus and Shoemaker (25) and Shoemaker et al., (22) who found no change in flow to the quadriceps and quadriceps and forearm muscles, respectively, regardless of the type of massage administered. Both studies concluded that massage did not induce changes in arterial or venous blood flow, and it was therefore unlikely that significant changes in total muscle blood flow occurred. In the current study, it was noted that FABF values at the mid-treatment point during massage were slightly elevated compared with the control trial, although this was not statistically significant. It did, however, lead us to investigate individual responses in FABF. In only one subject did FABF substantially differ between the massage and control trials. This may reflect variability in blood flow responses between individuals (20) or the difficulty analyzing blood flow over a short period of time (17).

Although arterial blood flow into the thigh was not significantly different between massage and control trials, SKBF and ST were significantly elevated after exercise and throughout the duration of massage in contrast to the control trial. Any changes in SKBF are thought to occur in order to meet the demands of thermal stress (14). This phenomenon was seen during exercise as increases in SKBF and ST occurred for both trials. During exercise, thermoregulatory reflexes are activated by the rise in body temperature (19). These reflexes inhibit vasoconstrictor outflow causing passive vasodilation of the cutaneous circulation and at the same time promoting the active vasodilator system. After exercise, with the commencement of massage, SKBF values continued to rise steadily as control trial values dropped back to baseline levels. A possible reason for this discrepancy in response could be due to the effects of friction from massage, which may cause increases in skin temperature that in turn will result in an

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increase in skin blood flow in order to dissipate the heat (3). The deep effleurage and pétrissage used in this study will have induced some surface friction between the therapist's fingers and the subject's skin (25).

It can be speculated that without an increase in FABF into the massaged leg, an increase in SKBF may be diverting blood flow away from deeper tissues such as muscle. While this may be happening, the total integration of FABF and SKBF is limited by the qualitative nature of the SKBF data as this is measured in arbitrary units there is no absolute value for the volume of flow. Thus, the absolute amount of blood diverted from the muscle could still be relatively small and physiologically insignificant. Some way of quantifying the distribution of flow may be a useful step in future research. Indeed it may be argued that, on the basis of MT and BLa data not being different between the massage and control trials, any diversion of blood flow from the muscle to the skin was relatively small.

The measurement of MT was made to provide further indirect and qualitative information with regards to muscle blood flow in the massage versus control trials. The removal of metabolically generated heat from skeletal muscle by blood has been calculated to be greater than the rate of heat storage (9). If massage increased muscle blood flow after exercise, it would seem reasonable to expect that muscle temperature would decrease more quickly as heat is transferred away. Conversely, if massage decreased muscle blood flow postexercise, this could result in higher muscle temperatures as heat is removed less rapidly. Muscle temperature values for the massage trial did not differ significantly from the control trial at any depth or time point. These results provide further indirect support for a lack of increase in blood flow through the muscle with massage. The data also suggest that any diversion of blood away from muscle to the skin as a function of massage is likely to be minor.

The physiological basis of rapid lactate removal stimulated by massage is through increased blood flow (3,4,16). With no increase in FABF between treatments, it is not surprising that the results of this study showed no difference in BLa concentration between conditions after exercise. These results do not support the once popular hypothesis that postevent sports massage promotes lactate clearance by increasing blood flow through the skeletal muscle bed and agree with previous research (2,5,10,12).

It is always pertinent to highlight possible limitations within the research design and in common with previous massage studies the timing and duration, as well as the amount of pressure applied with each type of massage, both within and between subjects, was difficult to standardize (4). Although we cannot expressly say the therapist was perfectly consistent, the use of an experienced physiotherapist replicates what would happen within a field/sport setting, thus increasing the ecological validity of this study. A further temporal limitation in massage studies is that it is not possible for valid logistical reasons, for some assessment procedures to be carried out throughout the massage. The presence of probes and thermistors throughout the duration of massage would limit the ability of the therapist to apply adequate treatment, thus potentially compromising the validity of massage trial results. Wherever possible, readings for temperature and blood flow were taken immediately after the cessation of each massage bout, and thus will represent the impact of massage to some extent. The volunteers in this study were not high-level athletes, and it is therefore possible, although unlikely, that different results may be seen in these populations.

Although an increasing number of authors are questioning the positive physiological effects of massage, Hemmings et al. (12) stated that there appears to be more evidence of positive effects of massage on athletes' perceptions of recovery from exercise. Further research into the effect of massage on psychological states, as well as developing from the current research with alterations in treatment time and adaptations to either the duration or type of exercise, are all possible considerations for future studies.

CONCLUSION

The results of this study do not support the hypothesis that postexercise massage elevates limb blood flow. This study adds to the previous body of knowledge as massage was seen to produce significant increases in SKBF and ST compared with the control trial. These results suggest that without an increase in FABF there is the potential for some muscle blood flow to be diverted to the cutaneous circulation. However, MT and BLa data in this cohort would suggest a limited metabolic and/or thermoregulatory impact of any muscle blood flow diversion. These results question the efficacy of postexercise massage of muscle in the recovery process from a physiological perspective.

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