

The Comparative Effects of Sports Massage, Active Recovery, and Rest in Promoting Blood Lactate Clearance After Supramaximal Leg Exercise

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Objective: To determine the comparative effect of sports massage, active recovery, and rest on promoting blood lactate clearance after maximal anaerobic (supramaximal) leg exercise.

Design and Setting: A counterbalanced experimental design with repeated measures was used. The repeated measures were the three treatment conditions. The order of the conditions was determined by random assignment to a counterbalanced test sequence. All data were collected in the Human Energy Research Laboratory at the University of Pittsburgh.

Subjects: Ten male competitive cyclists volunteered for this investigation.

Measurements: Serial venous blood samples were drawn and analyzed for blood lactate concentration for each test condition.

Results: There were significant main effects for both absolute and relative values of blood lactate concentration between the three treatment groups and across time within groups.

Conclusions: After supramaximal leg exercise, active recovery produced significant decreases in both absolute and relative measures of blood lactate concentration when compared with the sports massage and rest conditions. No significant difference was found between sports massage and rest for either absolute or relative changes in blood lactate concentration.

Key Words: anaerobic glycolysis, lactic acid, metabolic acidosis

Lactate metabolism and its rate of elimination from blood and muscle are important components of recovery following maximal exercise.¹ It has been well documented that performing low-intensity aerobic exercise (active recovery) during the immediate postexercise period is more effective in accelerating lactate clearance than inactive rest (passive recovery).¹⁻⁷

Active recovery promotes lactate clearance by increasing metabolic rate and systemic blood flow, thereby accelerating lactate metabolism via oxidation and gluconeogenesis.^{1,4,8,9} Although some controversy exists regarding the optimal intensity for active exercise recovery, a metabolic rate corresponding to 40% of maximum oxygen uptake (VO_2max) has been shown to be effective for accelerating lactate clearance following maximal exercise.^{1,2,4,6,7}

Sports massage is commonly used in an effort to facilitate lactate clearance despite the lack of controlled research to support its efficacy in this regard. Developed in the 1980s, sports massage incorporates classic Swedish strokes with

compression, trigger-point therapy, and cross-fiber friction techniques.¹⁰ It was "designed to provide therapeutic impact to meet the unique physical and biomechanical needs of athletes" and is typically divided into pre-event/postevent and maintenance routines.¹⁰

Specific massage techniques are thought to produce local increases in skeletal muscle blood flow via several mechanisms. Direct mechanical effects on tissue vasculature, circulatory changes secondary to the local release of vasodilators, and reflexive decreases in sympathetic tone elicited by direct tissue stimulation have all been proposed as possible explanations.¹¹⁻¹⁶ Theoretically, increases in skeletal muscle blood flow may accelerate the rate at which lactate is shuttled to various sites of elimination, thereby promoting its clearance.^{11,12,16} Previous studies concerning the effects of massage on skeletal muscle blood flow have been contradictory and difficult to compare due to differences in experimental designs, statistical analyses, and the massage techniques used.¹¹ However, Hansen and Kristensen¹³ reported that effleurage

produced a small and transient increase in blood flow. Hovind and Nielsen¹⁴ reported that petrissage had a variable and inconsistent effect on blood flow, while tapotement produced significant increases in blood flow comparable with exercise hyperemia. The compression stroke, the hallmark of sports massage, is reported to produce significant increases in skeletal muscle blood flow.^{15,17} However, there have been no studies to date that have examined the effect of the compression technique on either skeletal muscle flow or the rate of postexercise lactate clearance.

Currently, there is a lack of controlled research to support the efficacy of sports massage on accelerating the rate of postexercise blood lactate clearance. Therefore, the purpose of this investigation was to compare the effects of sports massage, active recovery, and rest in promoting blood lactate clearance after supramaximal leg exercise.

METHODS

Subjects

Ten male members of the Panther Cycling Club, ranging in age from 21 to 34 years, volunteered as subjects for this investigation (Table 1). Inclusion criteria for subjects were 1) males, 18 years of age or older, with similar aerobic fitness levels and years of competitive cycling experience; 2) no history of cardiovascular, orthopaedic, or metabolic disorders that may negatively affect the subject's ability to perform high-intensity exercise; and 3) no contraindications to massage therapy. Each subject received information regarding the risks and benefits of the investigation and gave written consent to participate. All procedures were approved by the University of Pittsburgh's Biomedical Institutional Review Board.

Experimental Design

This investigation used a counterbalanced experimental design with repeated measures under three experimental conditions: sports massage, active recovery, and rest (control). All subjects participated in each of the three experimental conditions. The order of the conditions was determined by random assignment to a counterbalanced sequence using the latin square technique.

Subjects were instructed to refrain from heavy physical exercise 24 hours before each testing session. Testing sessions were separated by at least 48 hours. The consumption of food and fluid, except water, was prohibited for 3 hours before each testing session. $\dot{V}O_{2peak}$ was determined for each subject on the first visit to the laboratory. After $\dot{V}O_{2peak}$ was determined,

each subject was then randomly assigned to the counterbalanced test sequence.

Testing Protocols and Equipment

$\dot{V}O_{2peak}$. We determined $\dot{V}O_{2peak}$ using a Monark cycle ergometer (model #818, Monark, Inc, Stockholm, Sweden) with a continuous protocol. Pedaling rate was 80 revolutions per minute and paced by a metronome. We increased the power output every 3 minutes. Subjects began the test at a brake force of 1.0 kg. We increased the brake force by 1.0 kg for stage 2, then by 0.5 kg for the remaining test stages. Our criteria for test termination were 1) inability of the subject to maintain the pedaling rate for 15 consecutive seconds (as determined by the principal investigator); 2) volitional termination by the subject due to exhaustion; or 3) a plateau of $\dot{V}O_2$ in presence of increasing power output. The subject then underwent a cool-down period of cycling at a low brake resistance until he felt sufficiently recovered.

The criteria for $\dot{V}O_{2peak}$ were the attainment of at least two of the following: 1) a plateau of $\dot{V}O_2$ in the presence of increasing power output, 2) respiratory exchange ratio (RER) greater than or equal to 1.1, or 3) heart rate \pm 5 beats per minute of the subject's age-predicted maximal heart rate. We determined the value for $\dot{V}O_{2peak}$ by averaging the two highest consecutive 30-second $\dot{V}O_2$ values.

We assessed heart rate before the test and during each exercise stage, using an Eaton Care Telemetry unit (Eaton Care, Inc, Ann Arbor, MI) with a CM5 electrode placement. We used a respiratory mouthpiece attached to a two-way Hans-Randolph respiratory valve (Hans-Randolph, Kansas City, MO) to collect expired gases. Respiratory-metabolic data (standard temperature, standard pressure, dry; $\dot{V}O_2$, $\dot{V}CO_2$, and RER) were determined every 30 seconds using an open-circuit spirometry system and on-line computer. Inspired ventilation was measured with a Rayfield Equipment RAM 9200 flowmeter (Ametek Thermox Instruments Division, Pittsburgh, PA). Expired gases were continuously sampled from a 5-L mixing chamber using Ametek CD-3A carbon dioxide and S-3A oxygen analyzers and an R-2 Flow Control Meter (Ametek Thermox). Raw data were continuously monitored by a Lawson Laboratories Data Acquisition program (Lawson Laboratories, Malvern, PA) and 12-bit A/D converter (Ametek Thermox). We calibrated analyzers with standard gases of known composition before and after each testing session.

Wingate anaerobic test. We used three successive Wingate cycle tests, with 2-minute rest intervals between each, to elevate blood lactate levels. The protocol calls for the subject to perform 30 seconds of "all out" (supramaximal) cycling at a

Table 1. Subject Characteristics*

Age	Height	Weight	$\dot{V}O_{2peak}$
24.5 \pm 3.98 yr	174.56 \pm 6.62 cm	69.90 \pm 5.46 kg	55.87 \pm 3.82 ml \cdot kg ⁻¹ \cdot min ⁻¹

* Values are mean \pm standard deviation.

very high braking force that was indexed to body weight.¹⁸ The Wingate test has been shown to rely on anaerobic glycogenolysis as the primary energy pathway, producing blood lactate concentrations ranging from 6 to 15 times above resting levels.^{18,19} All Wingate tests were performed on a Monark cycle ergometer interfaced with an IBM-compatible computer. We used a software package manufactured by Sports Medicine Industries, Inc (Version 102A, 1992, St. Cloud, MN) to determine the braking force for each subject and to generate an on-line analysis of anaerobic power. We used toe clips to maximize the involvement of both the quadriceps and hamstrings muscle groups.

Blood sampling. We obtained serial blood samples (2 mL) from an indwelling catheter (21-gauge) inserted into a prominent antecubital vein 10 minutes before exercise. The catheter was kept patent by infusion of a heparinized saline solution (0.4 mL/100 mL). Blood samples were obtained before exercise (resting sample), immediately after each Wingate cycle test, 5 minutes after the final Wingate cycle test, and at 5-minute intervals throughout each 20-minute experimental condition (samples 1–9, respectively). Blood lactate concentration (mmol/L) was analyzed using a Yellow Springs 2700 Select Biochemistry Analyzer (Yellow Springs Instrument Co, Inc, Yellow Springs, OH). The recorded value was the average of two readings per sample.

Sports Massage

The sports massage techniques we employed in our investigation are those typically used in a postevent routine (Table 2). We used the techniques of effleurage, petrissage, tapotement, and compression in an effort to increase blood flow through the previously active muscle beds. Effleurage is defined as any stroke that glides over the skin without attempting to move the deep muscle masses.²⁰ The technique is applied with firm, even hand pressure in the direction of venous return. Petrissage consists of kneading manipulations that compress and roll the skin and muscle under the hands/fingers.²⁰ Tapotement is any series of brisk blows that follow

each other in a rapid, alternating fashion.²⁰ Our protocol used two specific types of tapotement: pounding (closed fists) and hacking (ulnar borders of the hands). Compression involves conforming the hands to the muscle and applying a downward compressive force against the underlying bone, followed by a quick release.^{15,17} The technique is applied in a rhythmic fashion along the length of the muscle.

We used a 5-minute sports massage routine for each leg in both the supine and prone positions. Massage was first performed with the subject in the supine position, beginning with the right leg, then the left. The subject was then placed in the prone position and the massage continued, beginning again with the right leg.

The principal investigator, certified in sports massage, performed all massage therapy to ensure consistency within the experimental protocol. To ensure proper timing of techniques, we employed audio cues on a cassette recorder. A massage cream was used after the compression technique to decrease friction between the investigator's hands and the subject's skin.

Testing Procedures

After the third Wingate test, subjects remained seated for 5 minutes on the cycle ergometer without pedaling, allowing blood lactate levels to reach peak postexercise levels. At the end of this 5-minute period, a blood sample was obtained and one of the three experimental conditions was immediately initiated. The procedures for the three 20-minute treatment conditions were as follows: 1) during active recovery, the subject pedaled the cycle ergometer at 80 revolutions per minute at an intensity equal to 40% $\text{VO}_{2\text{peak}}$; 2) during the massage condition, the subject proceeded immediately to a massage table positioned next to the cycle ergometer; and 3) during the rest (control) condition, the subject proceeded immediately to a table positioned next to the cycle ergometer and remained lying in the supine position for 20 minutes.

Statistical Analysis

A *t* test was used to determine if blood lactate concentration increased as a result of the three successive Wingate tests. Significance ($P < .05$) was determined by comparing the mean of blood sample one (resting level) with the mean of blood sample five (peak lactate value) across all conditions.

To determine if there were significant changes in blood lactate levels as a result of the treatments, the absolute and relative changes were analyzed separately using a two-factor (treatment \times time) repeated-measures analysis of variance ($P < .05$). Absolute changes in blood lactate were expressed as a difference (mL/L) between the peak lactate value and the value at the end of the 20-minute treatment condition. Relative changes were expressed as a percent decrease from peak lactate concentration to the end of the treatment.

A Scheffe post hoc procedure was performed to probe significant main and interaction effects in absolute and relative

Table 2. Sports Massage Protocol

Time (min:sec)	Technique
Supine position	
0:00 – 1:00	Compression: lower leg/quadriceps
1:00 – 1:45	Effleurage: ankle to crease of hip
1:45 – 2:30	Thumb effleurage: anterior/lateral aspects lower leg
2:30 – 3:00	Petrissage: quadriceps
3:00 – 4:30	Tapotement: quadriceps
4:30 – 5:00	Effleurage: ankle to crease of hip
Prone position	
0:00 – 2:00	Compression: calf/hamstrings
2:00 – 2:30	Effleurage: ankle to upper thigh
2:30 – 3:30	Petrissage: calf/hamstrings
3:30 – 4:30	Tapotement: calf/hamstrings
4:30 – 5:00	Effleurage: ankle to upper thigh

changes in blood lactate between and within the three treatment groups.

RESULTS

Results of the *t* test revealed a significant increase ($P < .05$) in blood lactate levels after the Wingate cycle tests. This demonstrates that three successive Wingate cycle tests were an effective method for elevating blood lactate levels.

Analysis of variance indicated significant main effects for both absolute and relative values of blood lactate concentration among the three treatment groups ($F = 6.16, P = .009$ and $F = 31.52, P = .000$, respectively) and across time within groups ($F = 119.34, P = .000$ and $F = 162.78, P = .000$, respectively). In addition, a significant condition-by-time interaction effect was also found. Means and standard errors for absolute and relative changes in lactate responses among conditions across time are presented in Figures 1 and 2. Post hoc analysis indicated significant differences for both absolute and relative changes in blood lactate concentration between active recovery and sports massage and between active recovery and rest (control). When expressed in absolute terms, active recovery produced a mean decrease ($P < .05$) of 6.79 mL/L, compared with 4.39 and 4.33 mL/L for the sports massage and rest conditions, respectively. In relative terms, exercise resulted in a 59.38% decrease ($P < .05$) in blood lactate concentration, compared with 36.21% and 38.67% for the sports massage and rest conditions, respectively. A significant difference was found between sports massage and rest conditions at only one time point (15 minutes postexercise) for both absolute and relative changes in blood lactate concentration.

In summary, our results demonstrated that after supramaximal leg exercise 1) 20 minutes of sports massage performed on the involved limbs had no significant effect, when compared with the rest condition, on either absolute or relative changes in

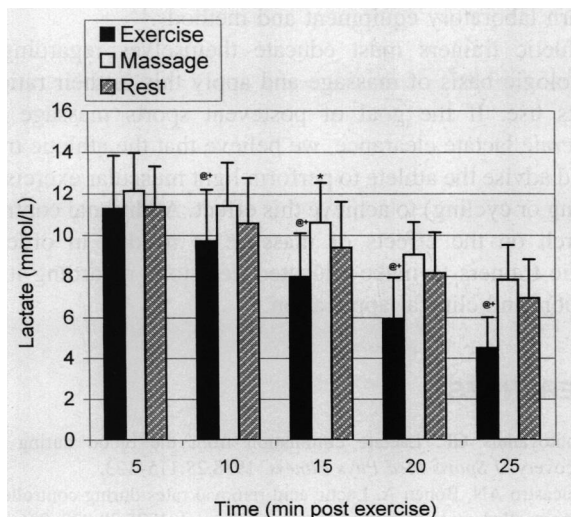


Fig 1. Absolute postexercise blood lactate concentration for exercise (E), massage (M), and rest (R) conditions. Symbols: * for M > R ($P < .05$); @ for R > E ($P < .05$); + for M > E ($P < .05$).

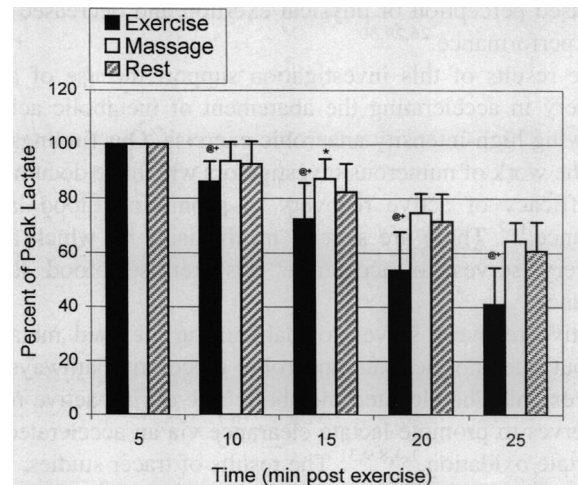


Fig 2. Relative postexercise blood lactate concentration for exercise (E), massage (M), and rest (R) conditions. Symbols: * for M > R ($P < 0.05$); @ for R > E ($P < 0.05$); + for M > E ($P < 0.05$).

blood lactate concentration, and 2) 20 minutes of active recovery exercise at 40% VO_{2peak} produced significant decreases in both absolute and relative values of blood lactate concentration when compared with the sports massage and rest conditions.

DISCUSSION

During short-term, dynamic exercise at maximal intensity, most of the required energy is provided through anaerobic glycolytic pathways leading to lactic acid production.^{19,21-25} At physiologic pH in the blood, the lactic acid molecule dissociates, yielding a hydrogen proton and a lactate anion.^{9,26} During this mode of exercise, it is the accumulation of hydrogen ions that decreases blood pH below the normal 7.4, resulting in metabolic acidosis.^{1,4,18,26-29}

Metabolic acidosis has been shown to be a major factor in muscular fatigue during short-term, high-intensity exercise.^{6,17,27-30} The resultant decrease in muscle force production consequent to lactate accumulation is, in turn, rate limiting for peak anaerobic exercise performance. Therefore, accelerating blood lactate clearance immediately postexercise may be beneficial for a succeeding bout of high-intensity exercise, particularly during athletic competitions that require multiple performances in a single day.²

Several mechanisms have been proposed to explain how metabolic acidosis predisposes an athlete to muscular fatigue. Within the exercising skeletal muscle, acidotic shifts in pH secondary to lactate accumulation serve to retard free fatty acid mobilization and slow glycolysis by inhibiting the activity of lactate dehydrogenase and phosphofructokinase. Both of these enzymes are important in regulating anaerobic energy production.^{1,2,4,7,26} In addition, high concentrations of intramuscular hydrogen ions may act to displace calcium ions from troponin, thereby inhibiting muscle contraction.^{1,4,26} Low blood pH has also been shown to stimulate pain receptors, contributing to an

increased perception of physical exertion and decreased muscular performance.^{26,29,30}

The results of this investigation support the use of active recovery in accelerating the abatement of metabolic acidosis following high-intensity anaerobic exercise. Our findings support the work of numerous investigators who have documented the efficacy of active recovery in promoting blood lactate clearance.¹⁻⁷ There are several mechanisms by which active recovery serves to accelerate postexercise blood lactate clearance.

Active recovery serves to maintain an elevated metabolic rate but does not activate anaerobic glycolytic pathways to a great extent. The elevated metabolic rate during active recovery serves to promote lactate clearance via an accelerated rate of lactate oxidation.^{1,4,8,9,31} The results of tracer studies, using isotope-labeled lactate, provide strong support for the conclusion that oxidation is by far the most significant pathway for lactate elimination, accounting for as much as 70% of lactate disposal.^{1,8,9,32}

Active recovery also promotes lactate clearance via an increased use of lactate as a fuel by the heart and contracting skeletal muscle.^{8,9,31} Lactate, which is produced in Type IIb fibers, is transported into Type I or IIa fibers, where it is oxidized.³³ Therefore, glycolytic fibers within an exercising muscle bed can shuttle oxidizable substrate (in the form of lactate) to neighboring cells with higher respiratory rates. The greater capillary density surrounding the slow-twitch fibers, coupled with their high lactate dehydrogenase enzyme content, suggests that the delivery, uptake, and subsequent oxidation of lactate is facilitated here.^{31,33}

The results of our investigation do not support the efficacy of sports massage in promoting blood lactate clearance after high-intensity anaerobic exercise. There are several factors that can account for our findings. The prevailing popular hypothesis is that postevent sports massage promotes lactate clearance by increasing blood flow through the skeletal muscle bed. Although there is evidence that some massage techniques increase regional blood flow through skeletal muscle,^{13,14} the magnitude of the increase may be overestimated. Cafarelli and Flint¹¹ reported that when effleurage is applied to a limb, the manual pressure applied does not directly increase arterial inflow, but serves to increase arteriolar pressure and empty the veins. Momentarily, this pressure produces a slight negative pressure in the veins that tends to draw blood in through the capillaries. The rate of blood flow is, therefore, transiently increased without an associated increase in metabolism. Similarly, Hansen and Kristensen¹³ reported that effleurage produced a small, transient increase in blood flow but concluded that even light muscular exercise would produce a greater circulatory effect. Hovind and Nielsen¹⁴ reported that petrissage did not significantly alter muscle tissue perfusion, concluding that the mechanical emptying of the vascular bed would not necessarily produce a net increase in blood flow, but may be effective for increasing lymphatic return. When describing the effects of tapotement, Hovind and Nielsen¹⁴ noted

that this technique produced immediate increases in blood flow comparable with changes associated with active muscular contractions. They reported that tapotement, specifically hacking, caused repetitive muscular contractions in the treatment area, producing increases in blood flow similar to those produced by voluntary muscular contractions. However, the report clearly stated that the technique was unpleasant to the subjects and would not usually be applied in a therapeutic setting as intensively as it was in the investigation.

Furthermore, evidence suggests that increases in blood flow alone have little or no effect on lactate clearance. Gladden et al³⁴ examined the effect of blood flow on net lactate uptake in a canine model. They reported that when metabolic rate and blood lactate concentration were held constant, a 65% increase in blood flow (above the baseline) had no effect on lactate uptake and subsequent clearance. It is our opinion that postexercise sports massage, as performed in this investigation, did not beneficially influence the pathways important to lactate metabolism and its subsequent clearance from blood and tissues.

Although the results of our investigation do not support the efficacy of sports massage in promoting postexercise blood lactate clearance, further research in this area may be justified. Examining the compression technique individually, increasing the treatment time, and determining muscle lactate concentration are possible considerations for future research.

CONCLUSIONS

Athletic trainers are frequently asked to perform sports massage by athletes who believe that these techniques will help speed recovery and enhance performance. Such claims are reported extensively in much of the popular massage literature. However, much of the supportive evidence for the positive effects of massage has been based on a vast body of anecdotal reports, rather than on sound scientific data obtained using modern laboratory equipment and methods.¹⁷

Athletic trainers must educate themselves regarding the physiologic basis of massage and apply this to their rationale for its use. If the goal of postevent sports massage is to accelerate lactate clearance, we believe that the athletic trainer should advise the athlete to perform light muscular exercise (ie, jogging or cycling) to achieve this effect. Additional controlled research on the effects of massage is needed in order for athletic trainers to make educated decisions regarding its use for sport and clinical application.

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