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BLOOD LACTATE REMOVAL USING COMBINED MASSAGE AND ACTIVE RECOVERY

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Abstract. The effect of combined massage and active recovery on blood lactate removal following a 30-s Wingate anaerobic cycling test (WAnT) was investigated. Maximum oxygen uptake (‡O_2max) was estimated for 25 healthy subjects using a YMCA incremental cycle test. After 5-min rest, subjects performed a WAnT and were then randomly assigned to a recovery condition: i) sitting rest (n=5), ii) leg massage (n=5), iii) active cycling at 37.5% ‡O_2max (n=5), iv) combined rest-active recovery (n=5) or, v) combined massage-active recovery (n=5). Blood lactate was measured from fingertip samples and analysed enzymatic-amperometrically. The relative reduction in blood lactate concentration was significantly greater in the active recovery group ($p<0.05$) and the combined massage-active recovery group ($p<0.05$) compared to the rest recovery group. Combined massage-active recovery may be favourable to active recovery since it more energy efficient and less uncomfortable.

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Key words: Wingate anaerobic test – Performance – Gluconeogenesis - Oxidation

Introduction

Rapid recovery is very important to athletes who engage in repeated bouts of high-intensity exercise. In certain sports, such as swimming, cycling, and athletics, competitors typically perform several bouts of exercise separated by short rest periods. Success in such events is therefore not only determined by an individual's ability to perform well athletically, but also by their ability to recover quickly. Sports massage is often used by athletes in the belief that it will accelerate recovery and thus enhance performance, however empirical evidence supporting this claim is limited and inconclusive [11,16,30].

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During high-intensity exercise, accumulation of blood lactate and the associated fall in pH are considered to contribute to the development of muscular fatigue [7,21,19,28]. The decrease in pH associated with elevated levels of lactate production may impede performance by inhibiting key glycolytic enzymes [20]. Lactate removal from the blood is therefore an essential aspect of the recovery process and crucial to the successful performance of repeated bouts of exercise.

Removal of blood lactate occurs through various mechanisms in the body. Tracer studies have shown that during exercise most of the lactate is taken up by skeletal muscle, reconverted to pyruvate, and then oxidised in the mitochondria via the Krebs cycle [8]. Previous research has demonstrated that the elimination of blood lactate can be optimised by undertaking active rest at 30-45% ‡O_2max since moderate activity increases the rate of pyruvate oxidation [1,9,14,17,26,29].

Some researchers have speculated that blood lactate removal might be accelerated during massage recovery due to increased blood flow [24,31,18,15,25], and therefore better distribution of lactate to lactate-consuming tissues [3,4]. However, since blood flow and the rate of lactate redistribution are likely to be near maximal following high-intensity exercise, it seems unlikely that massage could improve these factors during recovery. In fact, recent research has suggested that massage recovery is no more effective than rest recovery in promoting blood lactate removal [10,22,16].

Recently it has been reported that a combined active and massage recovery intervention is more effective than rest, and as effective as continuous active recovery for the elimination of blood lactate following a simulated 5 km cycling time trial [23]. However, interpretation of the contribution of massage to the recovery process in this study is difficult because the combined recovery interventions included an initial active phase. In the combined active-massage-active group, the effect of the massage phase on blood lactate reduction is consequently obscured by the initial active phase.

The purpose of this study was therefore to re-examine the effectiveness of massage and active recovery in terms of the elimination of lactate from the blood following an exhaustive bout of high-intensity exercise. The hypothesis was that blood lactate removal would be accelerated by active recovery and combined massage-active recovery, compared to rest, massage, or combined rest-massage recovery.

Materials and Methods

Design: A between-subjects experimental design was used in which 25 healthy subjects (33.9 yrs±8.9, 80.2 kg±11.8, and 176.3 cm±7.5) performed a WAnT and were then randomly assigned to one of the following five recovery conditions: i) 20-min rest (n=5), ii) 20-min massage (n=5), iii) 20-min active recovery (n=5), iv) 10-min rest followed by 10-min active recovery (n=5), and v) 10-min massage followed by 10-min active recovery (n=5). The dependent variable was the relative change in blood lactate concentration during recovery compared to the post-WAnT level. All subjects satisfactorily completed a health-screening questionnaire, and gave voluntary consent to participate in the experimental procedures that were approved by the University of Essex ethical committee.

Procedure: A Monark ergomedic 814E mechanically braked cycle ergometer was used to conduct YMCA cycling tests and 30-s WAnT. Throughout the 30-s WAnT, power output was recorded electronically on a personal computer using Cranlea Medical© software. Peak power was the highest power output recorded during the 30-s test period. Minimum power was the lowest power output recorded during the 30-s test period. Total work was the total work expended during the 30-s test period. Mean power was the average power output during the 30-s test. Fatigue index was the rate of decline in power output over the 30-s test expressed as a percentage of peak power.

The YMCA sub-maximal cycling test served as a warm-up, and was used to estimate ‡O_2max. During the YMCA test, subjects pedalled continuously at 50 rpm throughout four 3-min incremental stages. The flywheel resistance at each stage was determined by the subjects' heart rate response from the previous stage, and was calculated in accordance with the published guidelines of the American College of Sports Medicine [13]. Mean heart rate values for the last 30-s of each 3-min stage were plotted against the corresponding workload. The workload at age-predicted HR_{max} (220 - age in years) was determined by linear extrapolation. ‡O_2max was estimated using the published equations [27] based on predicted maximum power output. After the YMCA test subjects rested in the seated position for 5-min before completing a 30-s WAnT. After a 3-s acceleration phase, the resistance load [2] set at 0.075 kg per kg of body mass, was applied to the ergometer flywheel. Throughout the test, subjects were verbally encouraged to cycle at maximum effort.

Following the WAnT subjects rested in a seated position for 3-min, and then received the 20-min recovery intervention to which they had been randomly assigned. During rest recovery, subjects remained in the seated position for 20-min.

During massage recovery, subjects received a 20-min leg massage (Fig. 1a). During active recovery, subjects completed 20-min of cycling on the Monark cycle ergometer pedalling at 50 rpm against a flywheel resistance equivalent to 37.5% of the work rate at ‡O_2max [8]. During combined rest and active recovery, subjects completed 10-min of rest in the sitting position and 10-min of active recovery cycling. During combined massage and active recovery, subjects received 10-min of leg massage (Fig. 1b) followed by 10-min of active recovery. In the combined recovery conditions, the active recovery phase used the same conditions of cadence and intensity as the active recovery condition.

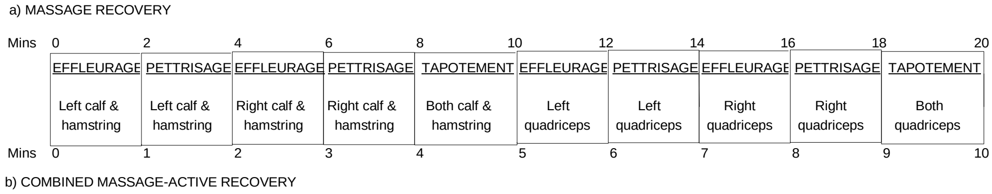

Fig. 1
Massage treatment protocol used for a) massage recovery and b) massage-active recovery

Whole blood samples were taken from subjects' fingertips using a Softclix® pro and collected in Analox capillary tubes containing an anti-clotting agent. Blood samples were taken at rest before the YMCA test, 3-min after the YMCA test, 3-min after the WAnT, 10-min into recovery, and at the end of recovery. The concentration of lactate in each sample was determined enzymatic-amperometrically using an Analox micro-stat P-GM7 after calibration using 8mM standard sodium lactate.

Results

Performance data and blood lactate concentration are presented as means with standard deviations. A between-subjects one-way analysis of variance (ANOVA) was used to compare the effect of different recovery interventions on performance measures and blood lactate concentrations. An alpha level of 0.05 was taken to indicate significance, and Tukey post-hoc tests were used to locate significant differences between the groups.

Table 1
Between group mean values of estimated ‡O$_2$max and active recovery workload

Recovery condition	Estimated ‡O$_2$max ml.kg^{-1}·min^{-1} (SD)	Active recovery workload W (SD)
Rest	50.3 (18.2)	N/A
Massage	51.9 (15)	N/A
Active	56.9 (8.5)	129.0 (31.1)
Rest-active	48.9 (11.7)	108.9 (24.4)
Massage-active	44.6 (4.7)	112.2 (11.5)

There were no significant differences between the groups in estimated ‡O$_2$max ($p>0.05$) or active recovery workloads ($p>0.05$). Subject descriptive data is presented in Table 1. There was no significant difference between the groups in WAnT measures ($p>0.05$). WAnT performance results are presented in Table 2.

There were no significant differences between the groups in pre-WAnT blood lactate concentration ($p<0.05$), and post-WAnT blood lactate concentration ($p>0.05$). The relative reduction in blood lactate concentration after the recovery period was significantly different between the groups, F(4,20)=3.4, $p<0.05$. Tukey post-hoc tests determined that the relative reduction in blood lactate concentration was significantly greater in the massage-active recovery group (-53.3%±14.2, $p<0.05$) and the active recovery group (-52.4%±12, $p<0.05$), compared to the rest recovery group (-23.4%±16.2).

The greater relative reduction in blood lactate was evident during the last half of the recovery phase (F=5.6, $p<0.01$), but not in the first half of recovery ($p>0.05$). A Tukey post-hoc statistical test showed that the relative reduction in blood lactate during the last half of recovery was significantly greater in the active recovery group (33%±16.1, $p<0.01$), the rest-active recovery group (36.2%±10.8, $p<0.01$), and the massage-active recovery group (35.7%±4.6, $p<0.01$), compared to rest recovery (-5.5%±2.4). Absolute blood lactate concentration values are presented in Table 3. Relative blood lactate concentration reduction is presented in Fig. 2.

Table 2
Group data for WAnT performance variables

Recovery Condition	Wingate Test Parameters Mean Power W (SD)	Peak Power W (SD)	Min Power W (SD)	Total Power J (SD)	Fatigue Index % (SD)
Rest	550	885	385	16530	16.8
	(135)	(266)	(59)	(4070)	(8.3)
Massage	639	1036	443	19180	19.9
	(116)	(204)	(69)	(3470)	(5.3)
Active	604	820	433	18400	13.1
	(61)	(57)	(63)	(1980)	(1.6)
Rest-Active	588	925	404	17640	17.5
	(69)	(163)	(47)	(2060)	(5.7)
Massage-Active	659 (144)	1098 (127)	453 (97)	19780 (4330)	21.9 (3.7)

Table 3
Blood lactate concentration (mM) at all sample points for each of the groups

	Sampling Points				
Recovery Condition	Rest Mean (SD)	Post-YMCA Mean (SD)	Post-Wingate Mean (SD)	Mid-recovery Mean (SD)	End-recovery Mean (SD)
Rest	2.1	3.1	9.6	7.8	7.3
	(0.5)	(2.2)	(2.8)	(2.4)	(2.6)
Massage	1.8	2.8	11.0	10.2	6.5
	(0.5)	(0.6)	(1.5)	(1.3)	(1.7)
Active	1.7	2.5	10.1	8.2	4.9
	(0.4)	(1.7)	(1.3)	(2.5)	(2.3)
Rest-Active	2.2	2.7	9.5	8.3	4.9
	(0.7)	(1.6)	(1.8)	(1.9)	(1.8)
Massage-Active	1.9	2.2	11.0	9.0	5.1
	(0.5)	(0.5)	(1.4)	(1.5)	(1.5)

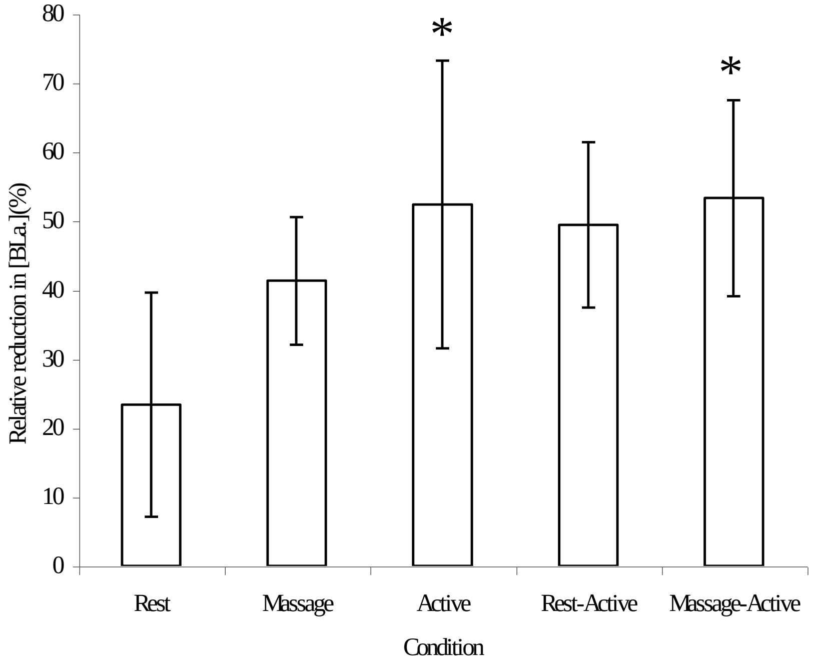

Fig. 2
Relative changes in mean blood lactate concentration [BLa.] for all recovery conditions measured between the first post-Wingate test peak value and the post-recovery value; *denotes significance difference ($p<0.05$) compared to rest. Error bars represent ±1SD

Discussion

The main finding of this study is that the rate of blood lactate removal during combined massage-active recovery is significantly faster than that during rest recovery, and as fast as that during active recovery. These results support the recovery-enhancing effects of combined massage-active protocols [23], and confirm the benefits of active recovery for blood lactate removal [1,9,14,17,26,29]. Furthermore, the results of the present study verify previous findings that massage on its own is no more effective than rest in terms of lactate removal [16,10,22].

Lactate transport across the sarcolemma, occurs through the processes of diffusion and active transport[5]. During maximal exercise, such as the WAnT, lactate is mainly produced as a result of type IIb fibre recruitment in the active muscles. This creates high lactate concentration gradients between the intra and extracellular compartments, which favours transport out of the cell across the sarcolemma and into the extracellular fluids. Thus the concentration of lactate in the general circulation rapidly increases. The displacement of lactate from inside the cell to the general circulation slows down as the concentration gradient of lactate across the sarcolemma diminishes.

Lactate is a gluconeogenic precursor at the liver, and is also transported to other sites including the heart, intestines, skin, and other skeletal muscles where it is oxidized and used as a source of energy[7]. The success of any recovery intervention is therefore largely dependent on lactate efflux from producing muscle cells, and the subsequent transport and delivery to sites of uptake and utilization.

During rest recovery, circulating lactate is removed slowly by gluconeogenesis and oxidization. During active recovery however, lactate elimination occurs more rapidly, predominantly through oxidation in the active type I and type IIa muscle fibres [7]. The continual turnover of lactate within the active recovery muscles fibres, maintains a concentration gradient that continually draws lactate across the sarcolemma from the extracellular fluid, thus gradually depleting the levels of lactate in the general circulation.

In the present study, the relative reduction in blood lactate concentration was greatest during the last half of the active recovery period. This observation does not necessarily indicate a diminished rate of lactate utilization during the first half of the recovery period, but may indicate that blood lactate concentration had not peaked three-min after the WAnT due to continued high rates of lactate release from the lactate-producing muscle cells into the general circulation.

The apparent enhancement of lactate removal by combined massage-active recovery is surprising given that only half the amount of active recovery cycling was performed compared to the active recovery group, and that massage recovery alone does not improve the rate of lactate clearance (Fig. 2) [16,10,22]. Even if massage does increase local blood flow, as previously suggested [3,4], it is unlikely that this would have any significant effect on lactate transport and uptake since perfusion of the active muscle capillary beds would already be maximal following a WAnT. Furthermore, the rate of lactate clearance in the rest-active recovery group approached statistical significance ($p<0.08$) and was therefore almost as effective as the active recovery and massage-active recovery conditions. These observations indicate that a short period of rest or massage may improve the lactate utilization potential of any subsequent bout of active recovery, but the underlying mechanisms of this effect have yet to be determined.

The massage portion of combined massage-active recovery may expedite lactate removal via hepatic gluconeogenesis [23]. The process of massage itself involves applying mechanical forces to the active muscles, which potentially increases intracellular hydrostatic pressure. The subsequent effect on the balance between hydrostatic and colloid osmotic pressures enhances the diffusion potential across the sarcolemma, thereby promoting rapid evacuation of lactate from the cell into the extracellular space. Consequently, massage may increase the availability of lactate for gluconeogenesis and oxidative utilization at other sites of uptake during the early stages of recovery. This mode of lactate uptake is supported by both present and previous observations that massage has a positive effect on lactate disappearance during the later stages of recovery [23].

A recent study reported significant increases in glycogen content in type I muscle fibres during a period of rest recovery, but not during a same period of active recovery [12]. This suggests that active recovery may impair this favourable effect with respect to the glycogen stores of the muscle. During rest, the volume of lactate consumed during hepatic gluconeogenesis may be less than during massage, probably due to sub-optimal rates of diffusion across the sarcolemma which subsequently has a rationing effect on the amount of lactate that is delivered and made available to the liver. Combined rest-active recovery and massage-active recovery both seem to improve the rate of lactate removal comparable to active recovery, but at a reduced energy cost.

It is concluded that combined massage-active recovery and active recovery resulted in significantly faster blood lactate clearance than rest recovery. Compared to active recovery, combined rest-active recovery and combined massage-active recovery are more economical in terms of energy cost and may have a glycogen sparing effect. These are desirable gains for top-level athletes whose success is often dependent upon subtle advantages over their competitors. Combined recovery interventions seem to be a viable alternative to active recovery since they are equally as effective at lactate removal, more energy efficient, and less uncomfortable.

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