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Comparative Effects of Upper or Lower Body Ergometry to Facilitate Recovery from High-Intensity Combined Arm and Leg Exercise

Benjamin Chad Lyman
University of Southern Mississippi

The University of Southern Mississippi

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by

Benjamin Chad Lyman

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Approved by

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Dr. Michael J. Webster
Associate Professor of Exercise Science

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Dr. Trenton Gould, Director
School of Human Performance and Recreation

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Dr. David R. Davies, Dean
Honors College

Abstract

The purpose of this study was to compare the effects of upper body versus lower body ergometry on blood lactate concentration ([La]) disappearance. Ten individuals (age: 20.6 ± 1.3 yrs, height: 1.72 ± 0.08 m, weight: 66.77 ± 10.42 kg) completed preliminary testing sessions, 3-5 days apart, to determine the power output corresponding with the subject's onset of blood lactate (OBLA), which for the purposes of this study is considered the subject's lactate threshold (LT), for leg ergometry (LT_L) and arm ergometry (LT_A). Participants then returned to the laboratory on three separate occasions to complete the experimental sessions. Each session consisted of a 5-min standardized warm up, followed by a 2-min high-intensity exercise bout of combined leg and arm ergometry, followed by a 15-min recovery and a half-mile performance trial. The 15-min recovery was randomly performed in one of three conditions: 1) performing leg ergometry (LE) at a power output corresponding with 80% of the LT determined for LE, 2) performing arm ergometry (AE) at a power output corresponding with 80% of the LT determined for AE, and 3) sitting passively on the ergometer (PAR). The mean recovery outputs were 115.9 ± 5.5 and 57.7 ± 2.9 W for the LE and AE, respectively. Comparing the three recovery modes for the percent decreases [La] clearance indicated no significant difference ($p > 0.05$). None of the three recovery modes resulted in significant time differences in the performance trial ($p > 0.05$). In conclusion, neither LER, AER, nor PAR showed any significance in being superior to one another in clearing [La] during recovery nor having any impact on exercise performance times.

Keywords: lactate concentration, lactate removal

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CHAPTER I: Introduction

Competitive swimmers often compete in multiple maximal effort swims during a single competitive session while having minimal recovery time between each swim bout. Confounding this issue is that quite often there is limited or no access to a pool for use during recovery. Active-recovery strategies have clearly been shown to be more beneficial than passive-recovery (Dodd, Powers, Callender, & Brooks, 1984; Ferreira, Carvalho, Barroso, Szmuchrowki, & Sledziewski, 2011; Greenwood, Moses, Bernardino, Gaesser, & Weltman, 2008; McMaster, Stoddard, & Duncan, 1989; Menzies et al., 2010; Toubekis, Peyrebrune, Lakomy, & Nevill, 2008a). However, considering the frequent constraints of time and facilities, practical recovery strategies are warranted to optimize subsequent performance.

One of the primary impacts from lactate accumulation is its alteration of acid-base balance. During intense exercise, 99% of lactic acid dissociates into a lactate anion and hydrogen cation (H^+), leading to metabolic acidosis (Ferreira et al., 2011; Gladden, 2004; Juel, 2001). Cairns (2006) reported that this only impacts skeletal muscle function when the intramuscular pH drops more than 0.4 units from the standard physiological pH of 7.0-7.1. A decrease in pH greater than this has been demonstrated to negatively impact skeletal muscle force production. The high glycolytic energy demand for physical effort lasting 1-10 min, which is case for most competitive swimming events, is likely to result in a severe metabolic acidosis (Hermansen & Osnes 1972; Sahlin et al., 1976). During repeated bouts of these types of activities, a primary goal during recovery is to rapidly facilitate the return of blood and muscle acid-base status back to normal thereby maximizing skeletal muscle force production during subsequent exercise

bouts/competitions.

It is generally recognized that active-recovery is more efficient than passive-recovery in clearing blood lactate following high-intensity activities (Dodd et al., 1984; Ferreira et al., 2011; Greenwood et al., 2008; McMaster et al., 1989; Menzies et al., 2010; Toubekis et al., 2008a). Potential factors shown to facilitate lactate clearance include an increase in blood flow, an increase in metabolic rate, and an increase in plasma lactate concentrations (Gladden, Crawford, & Webster, 1992; Gladden, Crawford, & Webster, 1994). High intensity exercise followed by an active-recovery protocol, stimulates all of these factors; thereby supporting the notion that active-recovery stimulates a greater removal of lactate than does passive-recovery.

When employing active-recovery protocols for swimming, there is much debate on the prescription of an optimal intensity (Dodd et al., 1984; Greenwood et al., 2008; McMaster et al. 1989). Earlier studies utilized an active-recovery intensity based on a percentage of the athlete's VO_{2max} (Dodd et al. 1984; McMaster et al., 1989). At issue with this is that a certain percentage of VO_{2max} used by one athlete may exceed the lactate threshold of another athlete (Greenwood et al., 2008). Others have simply prescribed the active recovery intensity as a percentage of the athlete's maximal swim velocity obtained during a 100-meter swim (Toubekis et al., 2008a; Toubekis, Smilios, Bogdanis, Mavridis, Tomakidis, 2006). More recently there is a trend toward prescribing a recovery exercise intensity corresponding to 80-100 percent of the athlete's lactate threshold to optimally reduce blood lactate levels to normal values (Ferreira et al., 2011; Greenwood et al., 2008; Menzies et al., 2010). This recent trend has become popular because it accounts for the significant variation in the lactate thresholds among individuals.

The purpose of this study was to compare lactate removal in response to using an arm ergometer or a leg ergometer as a means of recovery after a high-intensity bout of combined leg and arm ergometry. The premise for this is that not every competitive swimming venue will have the availability of a recovery pool; therefore, arm and/or leg ergometry would offer an alternate means to facilitate recovery between competitive events. Little research has examined the use of leg and/or arm ergometry as a means of active recovery for swimmers. It was hypothesized that the leg ergometry, given the greater muscle mass compared to the arms, will stimulate a greater removal of lactate during recovery from high intensity exercise.

CHAPTER II: Methods

Participants

Ten recreationally active individuals **(five male and five female)** volunteered to participate in this study. To be considered recreationally active, participants had to have been consistently exercising at least three days a week for one month prior to beginning the experiment. Table 1 summarizes the participants' characteristics. All subjects were asked to refrain from any form of exercise 24-h prior to each testing session. All participants provided written informed consent, which was approved by the university Institutional Review Board. All experimental testing sessions took place in the Laboratory of Applied Physiology at the University of Southern Mississippi.

Table 1 – Participant characteristics (*n*=10).

			Range	
	Mean	**S.E.**	**Minimum**	**Maximum**
Age (yrs)	20.60	0.40	19.00	22.00
Height (m)	1.72	0.03	1.60	1.83
Weight (kg)	66.77	3.30	51.26	85.73

Lactate Threshold Profiling Sessions

Participants completed two exercise-testing sessions, separated by 3-5 days, to determine their lactate threshold (LT) using a SciFit Pro2 combination arm/leg ergometer. During the first session, participants completed a test for the lactate threshold using the leg ergometer (LT_L). During the second session, participants completed a test for the lactate threshold using the arm ergometer (LT_A).

Upon arrival to the laboratory, each participant provided a 5-µL blood sample via earlobe capillary puncture for the measurement of resting [La] (Lactate Pro LT-1710;

Koyoto, Japan). For LT_L participants began pedaling the leg ergometer for 3-min at 60 W. At the end of 3-min another blood sample was collected for the determination of [La] and the power output was increased by 20 W. This process was repeated until the exercise elicited a [La] greater than 4.0 mM. For LT_A participants began pedaling the arm ergometer for 3-min at 30 W. At the end of 3-min another blood sample was collected for determination of [La] and the power output increased by 20 W. This process was repeated until the exercise elicited a [La] greater than 4.0 mM. For each test, the power output corresponding to a [La] of 4 mM was considered to be the participant's LT_L or LT_A.

Active and Passive Recovery Sessions

Approximately 3-5 days after completion of the tests for the LT_L and LT_A, participants returned to the laboratory for the first Experimental Testing Session (ET_1). Upon arrival they were assessed for resting [La] and then performed a brief, standardized 5-min warm-up bout of exercise at a relative level of 1.0 on the ergometer. After completion of the warm-up, participants performed a combined upper and lower body maximal exercise bout lasting 2-min at a relative level of 9.0 on the ergometer. The relative level of 9.0 was chosen based on pilot studies that showed this to be the most suitable resistance for increases in [La] levels sufficiently in 2-mins. One minute after completion of the maximal exercise bout, participants were randomly assigned to perform a 15-min recovery protocol consisting of either leg ergometry (LE), arm ergometry (AE), or passive recovery (PAR). The LE was performed using just the legs, and the AE was performed using just the arms both corresponding to an exercise intensity of 80% of their

previously determined LT for each respective exercise modality. The PR was performed with the participant sitting passively on the ergometer. During recovery, [La] was determined at 1, 3, 5, 7, 10, and 15-min. Immediately upon completion of the 15-min recovery, participants performed a maximal bout of combined ergometry exercise that required them to complete a half-mile performance trial as quickly as possible at a relative level of 5.0 on the ergometer. This level was chosen based on pilot studies that showed this to be the most suitable level for all participants to complete a half-mile within 2-mins, without large fluctuations in each participant's speed throughout the half-mile.

Approximately 3-5 days after completion of ET_1, participants returned to the laboratory for the second Experimental Testing Session (ET_2). This was identical to ET_1 with the only exception being that the modality of recovery exercise was one of the other forms of recovery (LE, AE, or PR). Finally, approximately 3-5 days after completion of ET_2, a third Experimental Testing Session (ET_3) was performed using the remaining recovery exercise modality (LE, AE, or PAR).

Statistical Analysis

A 3x6 analysis of variance (ANOVA) with repeated measures was used to test for significant differences among [La] during each of the recovery protocols. Separate one-way ANOVAs were used to test differences among performance trial times and differences among the percentage decrease of [La] during each of the recovery protocols. All data are presented as means ± standard error. Significance was set at $p < 0.05$.

CHAPTER III: Results

Figure 1 shows the [La] versus power output relationship for the lactate threshold profiling sessions for LT_L and LT_A. The LT_L and LT_A were determined by the power output corresponded to OBLA (4.0 mM) for the respective profiling session. The recovery power output was then determined by taking 80% of LT_L and LT_A. The mean power outputs for LT_L and LT_A were 115.9 ± 5.5 W and 57.7 ± 2.9 W, respectively.

Figure 2 represents the [La] during each of the three 15-min recovery protocols. [La] peaked at 5-7 min for LER, AER, and PAR (9.29 ± 1.00, 9.42 ± 0.90, and 9.43 ± 0.88, respectively) and progressively decreased over the remainder of the 15 min recovery. These values were higher than, but not significantly different ($p > 0.05$) from the values observed at the first minute of recovery for LER, AER, and PAR (7.36 ± 1.05, 7.44 ± 0.87, 6.03 ± 0.76 mM), respectively. After the 15-min recovery protocols, the [La] for LER, AER, and PAR decreased to 7.34 ± 0.64, 7.72 ± 0.83, and 8.06 ± 0.91 mM, respectively, and this was not significantly different between groups ($p > 0.05$).

Figure 3 represents the percent decrease in [La] from the maximum [La] observed during recovery. Percent decrease in [La] was 25 ± 5%, 24 ± 2%, 22 ± 3%, in LER, AER, and PAR, respectively, and were not significantly different between groups ($p > 0.05$).

Time trial performance following each of the three recovery protocols is presented in figure 4. Times following LER, AER, and PAR were 113.8 ± 3.1 s, 115.7 ± 1.6 s, and 113.0 ± 2.7 s, respectively, and were not significantly different between groups ($p > 0.05$).

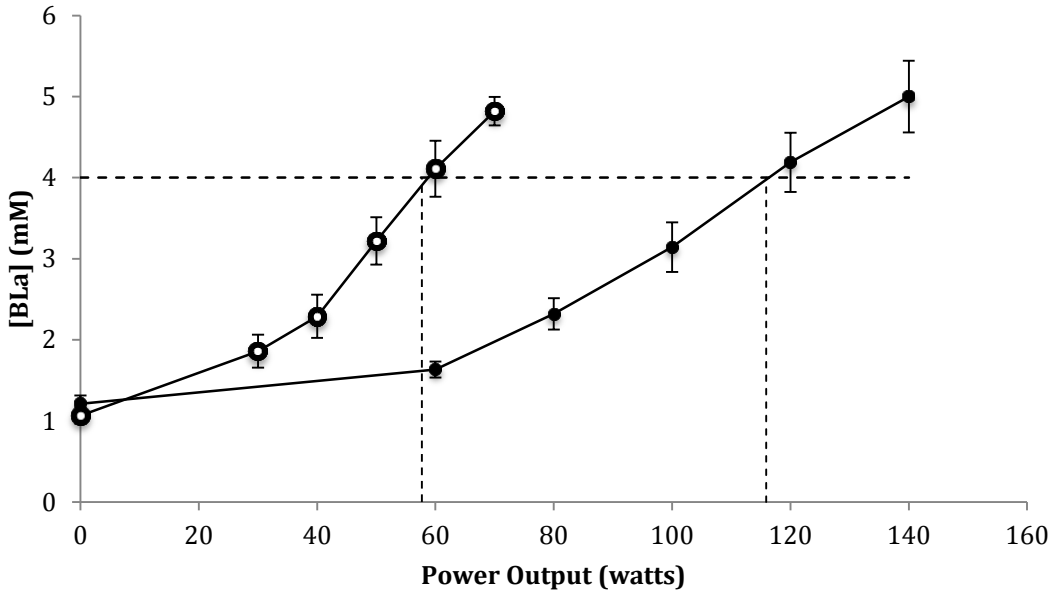

Figure 1. LT profiling session for leg and arm ergometry. The LT_L and LT_A were chosen to be the wattage that corresponded with OBLA (4.0 mM). Mean LT_L and LT_A were 115.9 ± 5.5 and 57.7 ± 2.9, respectively.

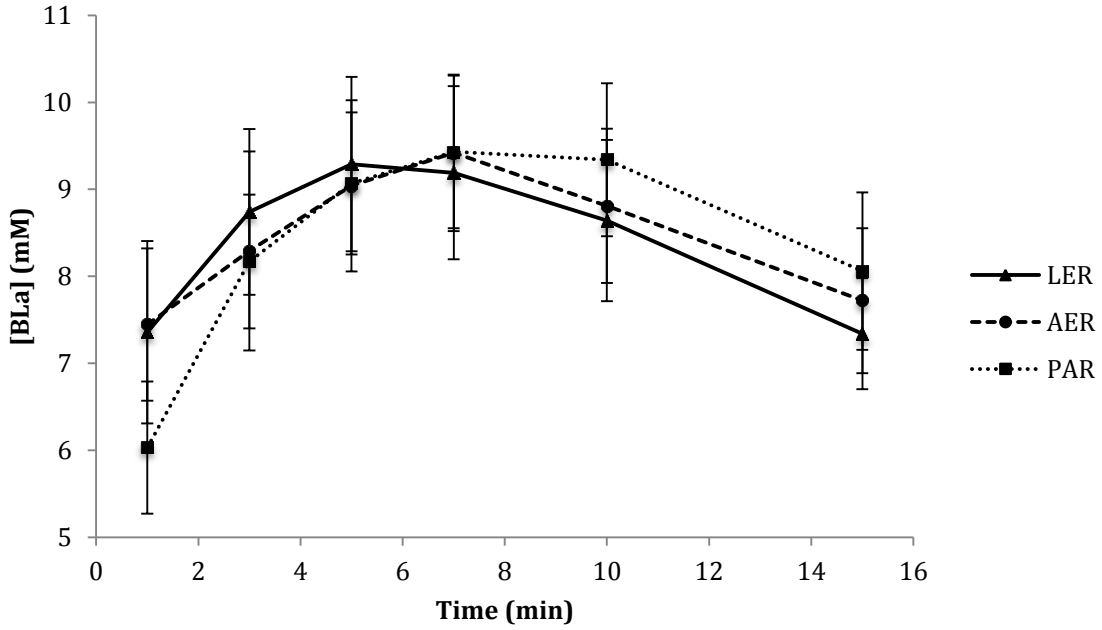

Figure 2. [La] (mM) recovery across LER, AER, and PAR. As expected, there were significant within group difference across time, however, there were no significant between group differences ($p > 0.05$). LER – Leg Ergometry Recovery, AER – Arm Ergometry Recovery, PAR – Passive Recovery

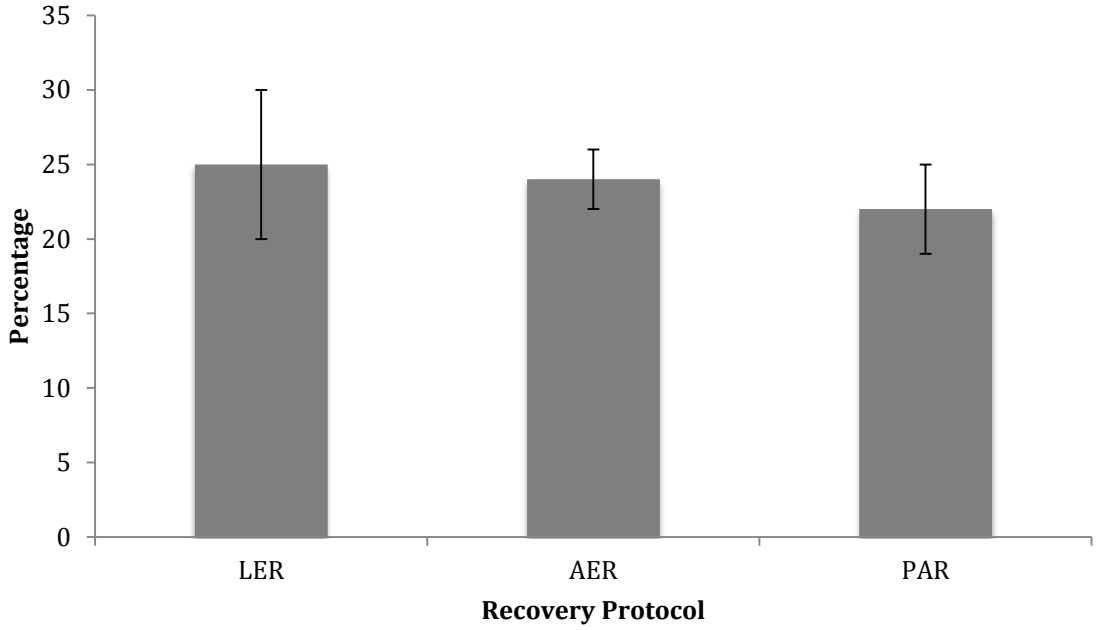

Figure 3. Percent decrease in [La] (mM) from the maximum [La] (mM) observed throughout LER, AER, and PAR. There were no significant differences between LER, AER, and PAR ($p > 0.05$). LER – Leg Ergometry Recovery, AER – Arm Ergometry Recovery, PAR – Passive Recovery.

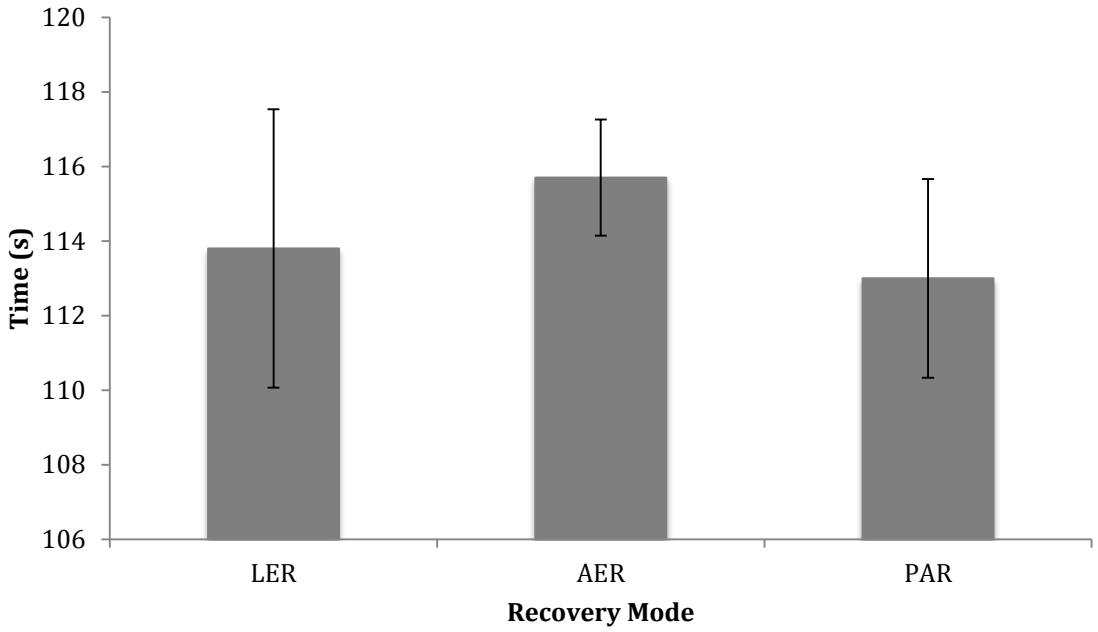

Figure 4. Performance trial time following LER, AER, and PAR. There were no significant differences in performance time between the three recovery modes ($p > 0.05$). LER – Leg Ergometry Recovery, AER – Arm Ergometry Recovery, PAR – Passive Recovery

CHAPTER IV: Discussion

The optimal protocol for the clearance of blood and muscle lactate during recovery has been debated for the past 30 years (Dodd et al. 1984; Menzies et al., 2010; Toubekias et al.; 2006). The present study compared lactate clearance using arm ergometry, leg ergometry, or a passive recovery in recovery from a high-intensity exercise bout of combined leg/arm ergometry. The application being that a competitive swimmer could use one or the other as a means of active recovery in the event that a recovery pool was not available at the competition venue.

The results of this study indicated that there were no significant differences ($p > 0.05$) in the percent clearance of [La] following a 15-min recovery of LER, AER, or PAR at 80% of the predetermined LT_L and LT_A. This is in contrast to previous findings, which demonstrated active recovery protocols to be more effective than passive recovery protocols in clearing lactate from the blood (Dodd et al. 1984; Ferreira et al., 2011; Greenwood et al., 2008; McMaster et al., 1989; Menzies et al., 2010; Toubekis et al., 2008a). However, it is important to note that although not significantly different, the decrease in the percentage of [La] accumulated throughout the protocol did decrease slightly more throughout both LER (25 ± 5%) and AER (24 ± 2%), when compared to PAR (22 ± 3%). Not surprisingly, the lack of difference in lactate clearance between the different recovery protocols was associated with no significant difference in the subsequent exercise performance time trial.

While the specific factors to account for the lack of significance between the different recovery protocols are only speculative, contributing factors may include a relatively small sample size (n=10), a relatively wide variation in the fitness level of the

subjects (recreationally active vs. competitive) (Evans, B.W., & Cureton, K. J., 1983), and/or possible gender response differences. Since the practical goal of this project was to evaluate the effects of leg ergometry and arm ergometry following a combined upper and lower body athletic event, such as swimming, having subjects perform pre and post recovery exercise in a pool would have been ideal. However, due to limitations in the availability of a pool, recovery exercise and performance trials were chosen to simulate this as closely as possible.

The primary objective of the current study was to compare lactate removal in response to using an arm ergometer or a leg ergometer as a means of recovery after a high-intensity bout of combined leg and arm ergometry. In summary, the findings do not support the hypothesis that following a high intensity combined leg and arm exercise, an active recovery of leg ergometry at 80% of LT_L is more beneficial than an active recovery of arm ergometry at 80% of LT_A or passive recovery.

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