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David R. Bassett Jr., Major Professor

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Date April 30, 1992

PHYSIOLOGICAL RESPONSES AND PERCEIVED EXERTION DURING LEG VERSUS COMBINED ARM-AND-LEG EXERCISE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

John Eugene Lewis

May 1992

DEDICATION

This thesis is dedicated to my Grandmother

Ailene W. Lewis

for her lifelong love, support, and guidance.

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Dr. David Bassett, my major professor, has guided me through the process of writing this thesis and given me the recommendations for helping me to complete this task. My other committee members, Dr. Ed Howley and Dr. Jean Lewis, have also contributed to the completion of my thesis with their expert tutelage. All three have been excellent instructors in preparing me to be a researcher and I am forever grateful.

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ABSTRACT

This study compared ratings of perceived exertion (RPE) and blood lactate (La) levels between leg (**L**) only and combined arm-and-leg (**A+L**) exercise on an air-braked ergometer. Eight college-aged males took part in the study, performing the two sessions in a crossover design at approximately the same time of day. Subjects exercised at approximately 75% of their measured maximum aerobic capacity for the two 40-minute bouts using a discontinuous protocol of four, 10-minute stages. Ratings of perceived exertion, heart rate (HR), oxygen uptake (VO2), and ventilation (VE) were recorded during the last 30 seconds of each stage. Using the finger stick method, blood samples were drawn within two minutes, at the end of each exercise stage, for analysis of La using the YSI-27 analyzer. A two-way repeated measures ANOVA (mode*time) revealed significantly lower RPE and La for **A+L** versus **L** exercise ($P < .05$). Non-significant differences for HR, VO2, and VE were observed between **L** and **A+L** exercise. The results indicate that for an absolute power output, RPE and La were higher for **L** exercise compared to **A+L** exercise.

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I. INTRODUCTION

Ratings of perceived exertion (RPE) are used in clinical and applied settings to quantify subjective, self-reported perception of effort during exercise. Borg's 15-point RPE scale is the most commonly used tool for this purpose (33). Variables which increase linearly with progressive work rates, most notably heart rate (HR) (6, 19, 42, 47, 48), correlate highly with RPE.

It has been shown that RPE are higher during arm (**A**) exercise compared to leg (**L**) exercise at the same absolute work rate (8). This finding is not surprising since HR, systolic and diastolic blood pressure, oxygen uptake (VO_2), blood lactate (La), and respiratory exchange ratio (RER) are higher during **A** exercise (2, 5, 11, 17, 18, 44, 51). However, it is uncertain whether further increases in active muscle mass (ie., the addition of arms to legs exercise at the same power output) would alter RPE. No differences have been observed at the same absolute work rate between HR, ventilation (V_E), and VO_2 during **L** versus combined arm-and-leg (**A+L**) exercise (3, 12, 23).

Eston and Brodie (16) found no significant differences at 49, 73.5, and 98 watts in VO_2, HR, V_E, and RPE between **L** and **A+L**. But, high exercise intensities were not examined and they did not analyze La during the exercise sessions. In men and women, Hagan et al. (23) found that HR, V_E, and VO_2 were similar between **L** and **A+L** exercise at all work rates, including maximum effort. Postexercise La levels revealed no differences between **L** and **A+L** exercise. Unfortunately, La was not measured during exercise and RPE were not taken. Extending the work of Eston and Brodie, Duey and Bassett (12) also found no significant difference at 98 watts for RPE between **L** and **A+L** exercise. However, a significant difference was observed for RPE between **L** and **A+L** at 147, 196, and 245 watts. This occurred despite the fact that HR, VO_2, and V_E were similar between **L** and **A+L** exercise. Additionally, blood La was not measured during the exercise sessions.

The purpose of this study was to examine the effects of adding **A** exercise to **L** exercise, measuring physiological variables associated with RPE, including blood La levels, HR, VO_2, and V_E,

while holding the total power output constant.

II. REVIEW OF LITERATURE

What is the optimum amount of muscle mass to use during aerobic exercise? More specifically, would one gain any benefit in exercising with **A+L** combined, as opposed to the **L**, during work at the same absolute power output using the same mode. Also, how are blood La levels and RPE affected by increasing the muscle mass involved in the exercise?

Researchers have examined many different variables, including RPE, blood La, VO_2, V_E, and HR to determine how they are related to exercise. The most prominent psychological factor tested is perceived exertion using Borg's 15-Point Ratings of Perceived Exertion scale. Investigators have shown that there are two main factors which dominate the sense of perception of the exercise: local factors of the exercising extremities (10, 14, 24, 32, 38, 39, 49) and a central factor stemming from the cardiorespiratory system (14, 15, 37).

While some research has demonstrated relationships between RPE with HR, VO_2, and V_E (19, 24), other research has

demonstrated no significant correlation between any particular variable and RPE (31). Questions remain as to how RPE correlates with, and is influenced by, blood La. While some studies have shown that RPE is not influenced by La during exercise (27, 31, 42, 49), others have demonstrated a significant correlation between the two variables (1, 14, 19).

A limited amount of information exists comparing blood La levels with RPE during fixed work rates while varying the amount of muscle mass. While the differences that exist between **A** compared to **L** work are without question, the comparison of **L** and combined **A+L** exercise gives less clear results. Many investigators (2, 8, 18, 51) have shown that at the same absolute submaximal work rate, RPE, HR, VO2, and RER are significantly higher during **A** exercise compared to **L** exercise. It has also been shown (3, 12, 23) that no differences existed between **L** and **A+L** exercise for HR, VO2, and VE responses.

A study by Secher et al. in 1977 was designed to observe differences between **A** and then **A+L** exercise versus **L** and then **A+L** exercise (45). For the first 10 minutes of the two tests, using a random design, the arms were exercised and then during

the last 10 minutes there was a combination of work. For the second test the same procedure occurred except for beginning with the legs. The most important variables measured in this study were VO_2, leg blood flow (during **L** and **A+L** work), and arteriovenous La and partial pressure of O_2. It was demonstrated that the highest VO_2 values occurred with the combined exercise as opposed to **L** or **A** exercise at submaximal work. Blood La also increased in response to adding the combination of limbs as opposed to one group of limbs only. These increases correspond to increases in HR once combined work commenced as well. The differences in HR and La were very small between both combined tests. Another significant finding was that adding strenuous **A** work to difficult **L** work caused a reduction in blood flow and VO_2 in the legs. However, when **L** work was added to **A** work, this reduction was still true, but not to the same degree.

The authors concluded that changes in exercising muscles precluded a change in La metabolism, more so in the arms than in the legs. However, it should be mentioned that the three kinds of exercise (**A**, **L**, **A+L**) were performed using different percentages

of VO2 max. The arms averaged 44% of max, the legs 67% of max, and combined work was 77% of VO2 max. Therefore you would expect La levels to be higher during the combined work since **A** exercise and **L** exercise may never have exceeded the anaerobic threshold (AT) as indicated by no La value being higher than 4 millimolar (mM) for these two modes of work. It was also interesting to note that RPE were not taken during this study.

Comparisons between **A** exercise and **A+L** exercise showed the **A** exercise to be perceived as significantly harder than the **A+L** exercise (16). Heart rate and blood La (30) also are found to be higher for **A** work as compared to **A+L** or **L** exercise. Obviously **A** work induces a higher HR response due to the higher pressor response of more static-like work, as opposed to more dynamic exercise when the leg muscles are utilized. It has been demonstrated that the more static the exercise is, the more dominant the local rating of exertion becomes (10, 14, 24, 39).

A study in 1974 by Klausen et al. was designed to determine the effects of training on the response of arterial and venous blood La samples obtained during submaximal exercise (30). Before and after the training program, arterial and venous La

samples were significantly higher for **A** work as compared to **L** work, at the same relative and absolute work loads. It was proposed that the level of anaerobiosis was higher in the arms than the legs due to the smaller amount of muscle mass being utilized.

Some investigators (9, 15, 34, 37) have suggested that central and peripheral factors interact to influence RPE during exercise. Significant correlations have been shown to exist between VO_2, VE, respiratory rate (RR), and blood La, with RPE (13, 14, 29, 35); however, others have reported no relationship (1, 31, 42, 49). Many authors have sought to eliminate any variables which might unknowingly influence the determination of RPE. A variety of studies have been designed to accomplish this including the use of different exercise modes (14, 19, 47), changing environmental conditions (29, 47), adjusting pedal rates (1, 35, 47), and altering the active muscle mass (10, 42).

One of the first studies testing the relationship between RPE, HR, and La, by Ekblom and Goldbarg (14), supported a strong relationship between the HR and RPE for **A** and **L** work, with

significantly higher values found for **A** exercise compared to **L** exercise. However, La levels were found to be virtually equal between **A** and **L** work, indicating no relationship between La levels with RPE. It was also demonstrated that for a given blood La concentration, no difference was found between RPE for treadmill and bicycle exercise. Another part of the study indicated that after an eight-week training program, for a given La level, no difference in before and after RPE values were found. In the final phase of the study, differences were found in the RPE between **L** versus **A+L** exercise, but La samples were not taken. The authors concluded that during very heavy work, the maximum amount of muscle mass should be used since it was related to a lower RPE.

Another of the early studies to examine the relationship among RPE, HR, and blood La was performed by Gamberale in 1972 (19). He compared the blood La, HR, and RPE responses to three different activities, lifting weights, pushing a wheelbarrow, and cycling on an ergometer. Lifting weights produced the highest RPE in relation to HR and the highest level of blood La in relation

to VO_2. However, the lowest values for perceived exertion in comparison to HR and the lowest blood La in relation to VO2 was found in pushing the wheelbarrow. It was concluded that independent of the work performed there was a linear relationship between HR and RPE. Due to the results of the study, it was proposed that as blood La levels increase in relation to VO2 the overall perceived exertion would increase as well as the perceived exertion of the exercising muscles.

Stamford and Noble (49) investigated the possibility of metabolic factors being the determinants of RPE in a study comparing absolute work rates using different pedal rpm on the cycle ergometer. A significant difference was found in RPE among 40, 60, and 80 rpm with 60 rpm having the lowest rated RPE. However, similarities among pedaling rates for HR, VO2, VE, and oxygen debt did not show a significant relationship between any of these variables and RPE. The authors suggested that feedback from the legs or other unknown factors could have a significant influence upon RPE.

Using two different breathing mixtures (air and 80% O_2-20% N_2) to influence certain physiological factors during exercise,

Allen and Pandolf (1) compared La and RPE responses at 50 and 80 percent of VO_2 max during treadmill exercise. Subjects performed both intensities of exercise with the different oxygen levels. Ventilation and HR were not significantly affected by breathing the hyperoxic mixture, whereas RPE was significantly lowered during the breathing of the mixture. Lactate was also significantly reduced during breathing of the hyperoxic mixture at 80% and 50% of VO_2 max. The results of this study indicate that La and RPE could be interrelated, without RPE being influenced by other physiological factors. The results also suggested that when a local factor, in this case La, can be reduced at the same percent of VO_2 max, the factor can control the level of the exertion felt by the subject.

Robertson et al., (40), studied the relationship of pedaling rates on a cycle ergometer to perceived exertion measured locally and overall. The perceived exertion for the legs was significantly higher than for the overall rating for 40, 60, and 80 rpm. Results of the study were in agreement with a study by Pandolf et al (38) where it was concluded that central cardiorespiratory signals

were not as prevelant in determining RPE, due to focus of local sensations in the legs. Other studies have resulted in findings of a locally dominated exertion signal in cycling (10, 39, 53).

The study by Robertson et al., (40) even demonstrated a difference in perceived exertion due to the amount of muscle mass utilized with a legs only design between varying intensities of work (39, 53). The highest exertion rating was observed during the 40-rpm session and the rating decreased with increasing rpm. The higher intensity work during the 40-rpm session was assumed to require less muscle mass than the higher rpm sessions (10, 49).

In the follow-up study by Robertson, et al., (41) perceived exertion once again was higher at 40 rpm as compared to 60 and 80 rpm. However, there was no significant difference found in levels of blood La among the three work rates. These results compared favorably with studies done by Pandolf and Noble (39) in 1973 and Stamford and Noble (49) in 1974. It has been suggested that perceptions of leg exertion is related to local signals (9, 14, 38). Since these local signals were related to an output of increased anaerobic metabolism (1, 19), the

investigators expected to see a higher blood La concentration during the 40-rpm session compared to the 60 and 80 rpm sessions. But, this did not occur as the La samples were similar for all three work rates.

In a similar study design by Lollgen et al (31), no significant relationship was found between La and RPE after the factor of power output was deleted by statistical analysis. The authors concluded that the chemoreceptors located in the muscle were not involved in local perception rating. In this study on the cycle ergometer, pedal rate varied from 40 to 100 rpm while power output was held constant. No correlations were demonstrated between HR, VE, and VO_2 with RPE, agreeing with the results of other studies (9, 10, 32, 39). It was proposed by the authors that the relationship between RPE and these variables is not causal, but due to the reliance on work load (37).

A study by Borg et al (7) was designed to distinguish between HR, RPE, leg pain, and blood La during an exercise session on a cycle ergometer. They found that all variables increased with increasing work rates and contained correlational effects, but not

necessarily absolute effects. In other words, HR increased linearly, but the other variables increased exponentially and were not necessarily the result of a cause and effect relationship. This study suggests that RPE are related to a combination of factors rather than any single factor.

Another study by Borg and associates (8) was designed to compare the values from the RPE scale and the category ratio (CR) scale, as well as with HR and blood La from arm cranking and leg cycling. The study revealed that as work intensities increased so did the HR, RPE, CR, and La values for both **A** and **L** exercise, but more so for **A** exercise. The authors concluded that the smaller amount of muscle mass in the **A** exercise to perform the same amount of work caused blood flow to accelerate, HR to increase, and RPE to rise in relation to the **L** work. The investigators concluded that the increase and/or variation in RPE could be explained by a combination of blood La and HR.

A recent study from Seip et al. (46) investigated the relationship between RPE and blood La in trained and untrained individuals. Because evidence has suggested a relationship between La and local exertion (34), the authors tested the effect

of training state on this relationship. Significant differences were found between runners and non-runners in highest treadmill velocity, VO_2 max, V_E, and ventilatory equivalent (V_E/VO_2). However, there were no significant differences in local and central RPE at the peak velocity. At the AT and fixed blood lactate concentrations (FBLC) of 2.0, 2.5, and 4.0 mM the trained subjects showed a higher average treadmill velocity, V_E, VO_2, and HR other than HR at 4.0 mM, in comparison to the untrained. If one can assume no differences occur in La levels between runners and non-runners at the AT and at FBLC of 2.0, 2.5, and 4.0 mM, then it is thought that La is an effective indicator of local exertion regardless of training state. The authors also felt that training state had no influence upon the subjects' ability to perceive overall or differentiated RPE values at the AT or FBLC in horizontal treadmill work. The data also did not support V_E as being a strong indicator of central levels of exertion.

The second study from this laboratory conducted by Hetzler et al. (26) consisted of comparing different modes of exercise and how that might influence perceived exertion at different La

levels. During cycle ergometry and treadmill work, it was found that perception of exertion changes as do the levels of La change. At the AT, RPE was constant regardless of the mode of exercise even though it has been found that La levels are higher for a given percent of VO_2 max or HR in cycling as compared to treadmill work, because of a suggested higher level of static work in cycling (25). Once again, research from this lab showed that higher levels of La can significantly increase the values of RPE, although how this actually happens is still unknown.

Eston and Brodie (16) compared **A**, **L**, and **A+L** exercise on an air-braked ergometer to determine what differences might occur in RPE, HR, V_E, and VO_2. Responses were observed at 49, 73.5 and 98 watts. It was found that RPE, HR, V_E, and VO_2 were significantly higher during **A** exercise as compared to the other two forms of exercise. No significant differences were found in these variables when **L** and **A+L** exercise were compared. Because La was not measured, the authors were limited in their explanation of the results of the study.

Arm, leg, and arm-and-leg exercise were compared on the

Schwinn Air-Dyne by Hagan et al. (23) to determine any relationships between HR, VO_2, VE, and pre-and post-exercise La. Heart rate attained at maximum exercise was significantly higher for **A+L**, than either **A** or **L** exercise. Maximum oxygen uptake in **A+L** exercise was also significantly greater than the value observed for **A** work. Post-exercise values for La showed statistical significance for **A** as compared to **L** exercise, but were nonsignificant compared to **A+L** exercise. In each submaximal exercise stage, VO_2 and VE were significantly higher in **A** exercise compared to **A+L** and **L** exercise, whereas RER was found to be similar between all three types of work for each stage. The authors proposed that because La levels were higher in arm cranking exercise as opposed to leg cycling, the higher La production resulted from more glycolysis occurring in the arms in response to increased hypoxia.

Duey and Bassett compared the RPE between **L** and **A+L** exercise at the same absolute power output during a stepwise progression in work rate to exhaustion (12). While no significant differences were observed for HR, VO_2, and VE, overall RPE were found to be significantly lower at the moderate power outputs for

A+L exercise compared to **L** exercise. Similar to Eston and Brodie, Duey and Bassett did not observe a difference in RPE at 98 watts, nor did they observe a difference at maximum effort (12). The authors concluded that RPE was not influenced by the central factors, but some unknown factor, such as blood La which was not measured.

Therefore during a comparison between **A+L** and **L** exercise at the same absolute power output, it would seem that more muscle fibers would have to be activated in the **L** work to maintain the same intensity. Since it has been previously shown that more fiber utilization increases RPE, as well as La production (41), one might suspect differences in these variables comparing **A+L** versus **L** exercise. Also, during combined **A+L** work a subject is able to adjust the amount of work the arms or legs are accomplishing. If one feels fatigue in the legs, (s)he can increase the arms' output to allow the legs to "rest". Whereas in the **L** only exercise, there is no way to adjust the amount of work distributed throughout various limbs. So the legs are required to continually recruit more and more fibers, until either the end of

the exercise session or exhaustion.

This could be very important to the individual interested in beginning an exercise program. While it is impossible to keep La buildup from occurring during exercise, it could be possible to choose forms of exercise which might limit this buildup. Increasing La levels are associated with increased acidosis in the blood and subsequent fatigue (52). Someone beginning an exercise program could benefit from the knowledge of what mode of exercise to perform, as well as the proper training intensity. Since increasing intensities of exercise correspond to higher La levels, a novice exerciser should start out at a more moderate intensity. For sedentary people duration, rather than intensity, would be the main focus for increasing and sustaining participation in an exercise program. Therefore if it could be demonstrated that **A+L** exercise would result in less La being produced compared to **L** exercise, a longer, less painful duration of exercise could occur.

III. METHODS

Eight healthy males participated in three exercise sessions. All subjects were physically active and they had no prior history of cardiac impairments. Their age, height, weight, and VO_2 max were (mean ± SD) 26.75 ± 4.03 yr, 179.71 ± 4.85 cm, 81.62 ± 10.84 kg, and 4.02 ± .49 l/min. Each subject signed an informed consent form (see Appendix A) approved by the Human Subjects Committee of the University of Tennessee, Knoxville, which outlined the risks associated with exercise testing.

Ambient conditions during all testing were (mean ± SD) 21 ± .9 °C, 739 ± .7 BP (mm Hg), and 24 ± 5 RH (%). Subjects were required to complete three separate exercise tests to fulfill the total requirements of the study. The first session consisted of a VO_2 max test to exhaustion on a Schwinn Air-Dyne using both arms and legs. For this test, the subjects were required to increase in power each minute until the output could no longer be sustained. A blood sample was taken at rest and at three minutes post-exercise for the determination of blood La. The VO_2 max

value was used to derive the work rate for the two remaining tests.

Subjects then performed one of the two 40-minute tests, using either **L** or **A+L**, at approximately 75% of VO_2 max. Using a counter-balanced design to reduce the chance of order effect, subjects performed one of the tests and then rested at least forty-eight hours before the next test to assure proper recovery. Subjects were advised not to participate in vigorous physical activity prior to the tests. To account for diurnal variations, testing time occurred within the same time of day as the initial session.

All metabolic data was monitored with the use of the Rayfield system (Rayfield Equipment, Waitsfield, VT). Inspired VE was measured using a RAM 9200 air-flow meter. The percentage of O_2 and CO_2 in expired air were sampled by an Applied Electrochemistry Model S-3A analyzer and a Beckman LB-2 analyzer, respectively. These gas analyzers were integrated into the Apple II+ and Rayfield system to yield VO_2 and VE values every minute. The gas analyzers were calibrated with gases of known concentration analyzed by the Scholander method (43).

Heart rate was monitored using a telemetry unit strapped to the chest (UNIQ Heartwatch Model 8799). Oxygen uptake, V_E, and HR were measured at rest and during the final 2 minutes of each 10-minute interval.

The 15-point RPE scale developed by Borg was used during the exercise sessions (6). Before each testing session, the subjects were given a set of standard instructions to read (see Appendix B) for estimating the overall RPE. At 20 seconds before the last minute of the stage, the subject was asked to give a rating of perceived exertion. Prior to the collection of RPE, HR, V_E, and VO_2 were measured, so as not to influence the RPE score.

Immediately afterward the subject stopped exercise and the blood sample for La analysis was taken. Total time taken for the sampling procedure was two minutes. Lactate was sampled from the finger tip using a microlancet (7, 28). Between 100-200 microliters of blood was withdrawn from the finger into a glass spot plate containing sodium fluoride. The blood was transferred with a 25 microliter syringepet from the spot plate to blood tubes containing cetrimonuim bromide, a cell lysing agent, and

sodium fluoride. Blood samples were then analyzed using the YSI-27 industrial analyzer (Yellow Springs, OH). Prior to the study an enzymatic method (22) of La analysis was used to verify the values of the analyzer. Zero, 5, and 15 mM standards were used to calibrate the machine for the blood-tube samples.

A two-way repeated measures ANOVA (exercise mode * time) was used to analyze all exercise variables. The significance level was set at $P = .05$ for all comparisons. Resting values were not analyzed during any statistical analyses.

IV. RESULTS

Individual values, means and standard deviations for HR, VE, VO2, La, and RPE at each time are presented in Appendix C (Table C-1 through Table C-5, respectively). All variables demonstrated a significant difference over time ($P < .05$) for **L** and **A + L** exercise. Values for VO2 (see Figure 1), HR (see Figure 2), and VE (see Figure 3) increased slightly over time. No significant differences ($P > .05$) were observed for VO2 (Table D-1, Appendix D), HR (Table D-2, Appendix D), and VE (Table D-3, Appendix D) for **L** versus combined **A+L** exercise.

Ratings of perceived exertion (see Figure 4) increased steadily during **L** and **A+L** exercise. Ratings of perceived exertion for **A+L** exercise were significantly lower ($P < .05$) as compared to **L** exercise (Table D-4, Appendix D).

Blood lactate values (see Figure 5) increased after the first 20 minutes during **L** and **A+L** exercise and then declined. Lactate levels during **A+L** exercise were significantly lower ($P < .05$) compared to **L** exercise (Table D-5, Appendix D).

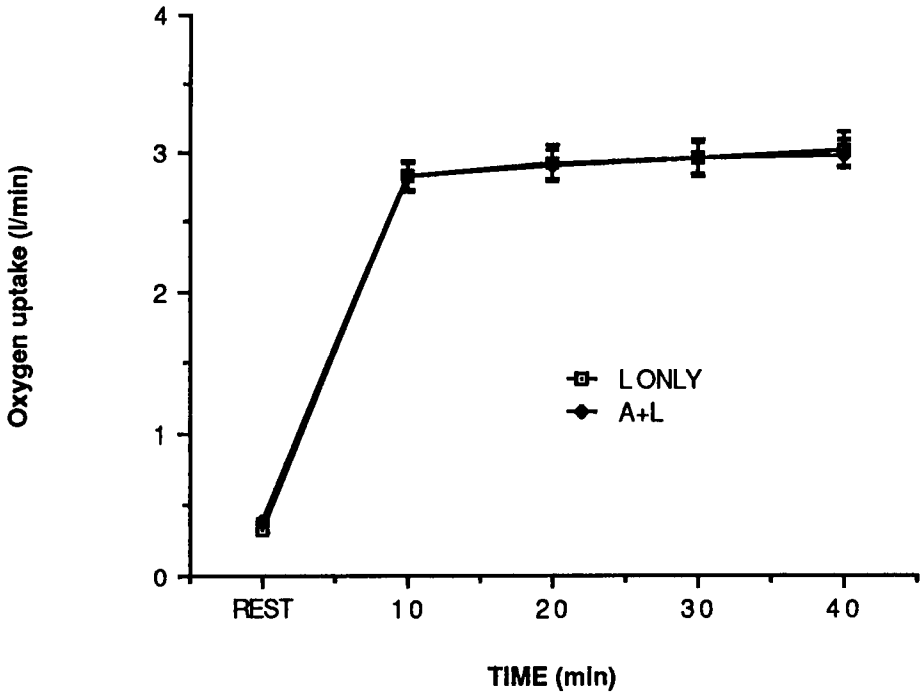


Figure 1. Oxygen uptake versus time for **L** and **A+L** exercise

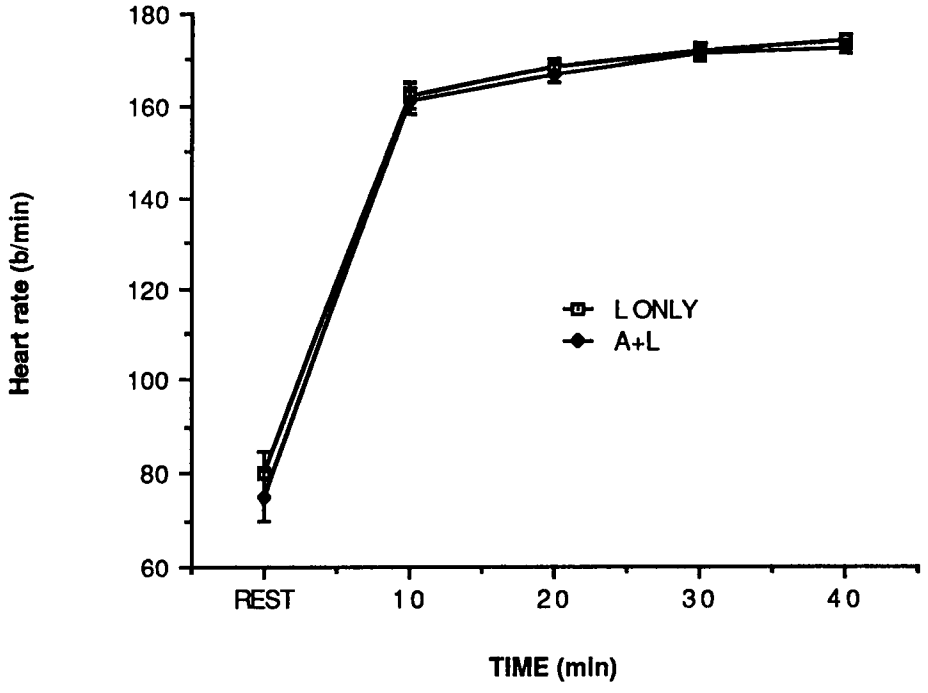


Figure 2. Heart rate versus time for **L** and **A+L** exercise

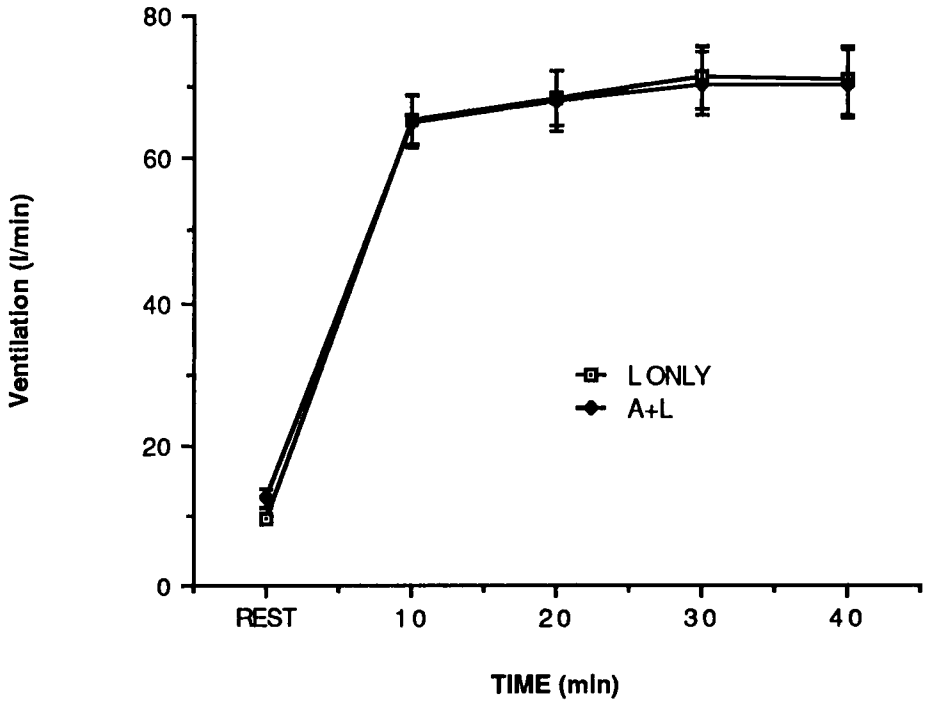


Figure 3. Ventilation versus time for **L** and **A+L** exercise

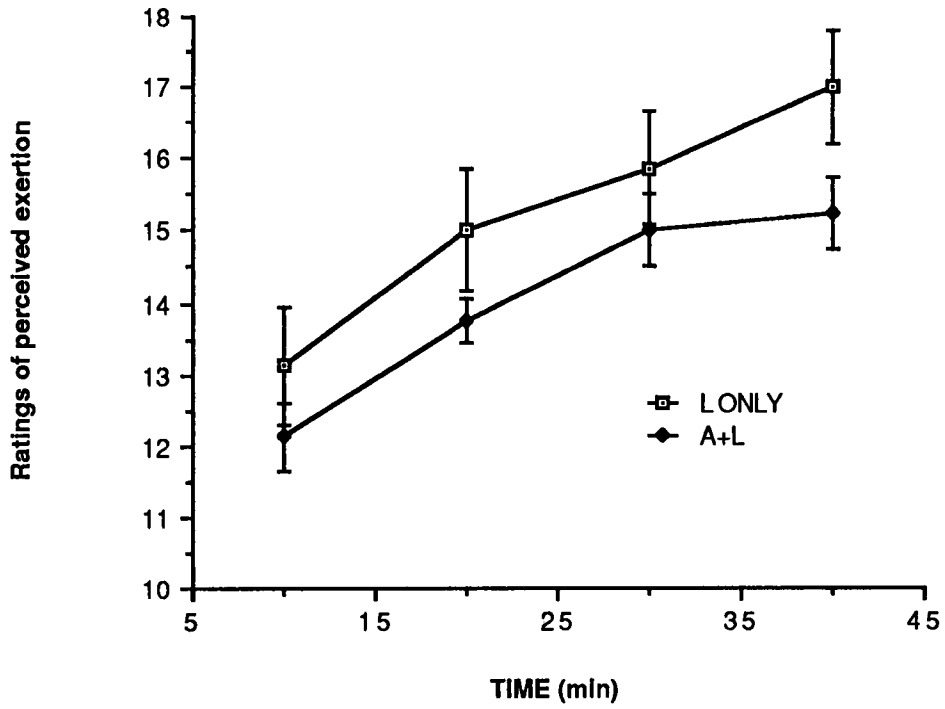


Figure 4. Ratings of perceived exertion versus time for **L** and **A+L** exercise

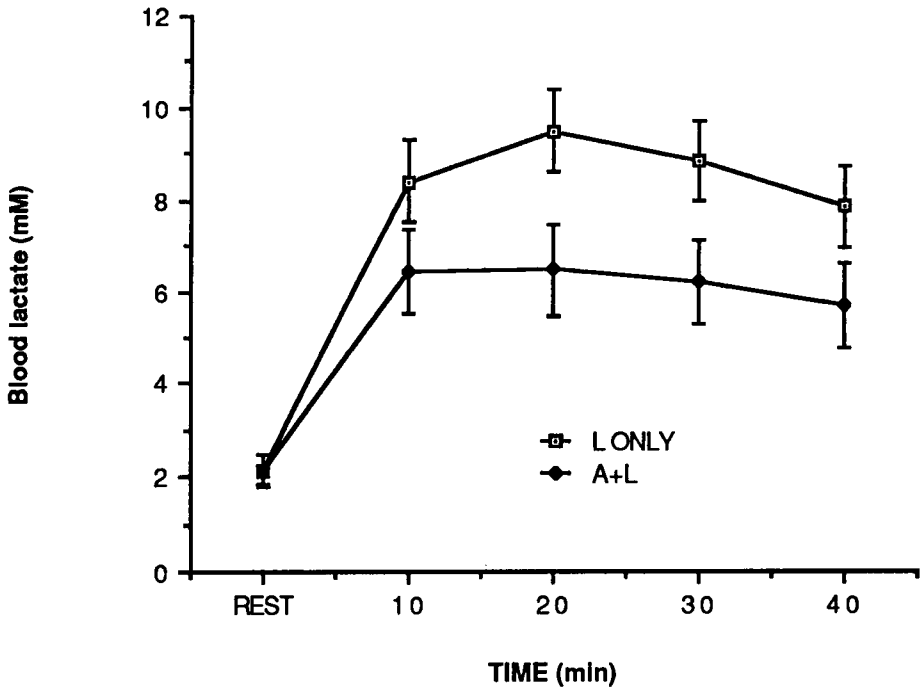


Figure 5. Blood lactate versus time for **L** and **A+L** exercise

V. DISCUSSION

The results of the present study indicate that significant differences exist in RPE and blood La levels during **L** versus **A+L** exercise. At the same absolute work rate, and despite no differences between HR, VE, and VO2, **L** exercise resulted in greater blood La accumulation and higher RPE values than **A+L** exercise.

It is widely accepted that **A** exercise elicits greater HR, VE, VO2, and La values than **L** exercise at the same absolute work rate (2, 17, 18, 44). Thus, it is not surprising that RPE values are higher in **A** exercise than **L** exercise (8).

However, the results of adding **A** exercise to **L** exercise have been inconsistent. Bevegard (5) found no differences in La levels between **L** and **A+L** at the same work rate. Although some investigators (20, 50) have shown that the additional use of arms increases VO2 max, others have found different conclusions. Secher et al., (45) have shown that the addition of **A** exercise to **L** exercise caused no further increase in VO2 max values. Astrand and Saltin have also found no differences in VO2 max between **L**

and **A+L** exercise (3). Hagan et al., found no differences in VO_2 at submaximal and maximal levels between **L** and **A+L** exercise (23). In addition to VO_2, other investigators have found HR and V_E between **L** and **A+L** exercise to be non-significantly different (12, 16, 23). Consistent with these investigations, the present study also demonstrated similar values for VO_2, V_E, and HR between **L** and **A+L** exercise.

The present finding of a significant difference in RPE between **L** and **A+L** exercise is consistent with the results of Duey and Bassett (12). They reported differences in RPE at intermediate work rates (147, 196, and 245 watts) during a progressive exercise test (12). The results of these studies, reveal differences in RPE at submaximal work rates in the range of 60-85% of VO_2 max. These work rates correspond with intensity levels which most people would utilize in a conditioning program (21).

In addition to the difference observed in RPE between **L** and **A+L**, significantly higher La values were demonstrated for **L** work. The highest blood La levels occurred within the first 20

minutes and then the levels slightly declined. These results are consistent with the work of Bang (4), who showed that during light to moderate steady-state exercise, blood La levels rose initially and then declined over time. Mihevic also points out that La will reach a plateau and then decline during prolonged steady-state work (33).

Since the HR, VO2, and VE responses were nearly identical for **L** versus **A+L** exercise, one might label these factors as being secondary to the input of RPE. Also, since La was significantly higher during **L** exercise, one could propose that La is more closely linked to RPE than these other factors. However, La is not the only variable influencing RPE, as demonstrated by the fact that La fell after 20 minutes of exercise, whereas RPE continued to rise. This is consistent with the work of Noble (36) who found that RPE rose continuously during four 3-minute steady-state exercise tests. These results would suggest a complex interaction among different physiological variables that provide input to RPE (13, 42). However, the intent of this study was not to examine which central or peripheral factor is the primary determinant of RPE, but rather to examine how the addition of **A**

exercise to **L** work would affect RPE.

Although the addition of **A** exercise to **L** exercise has questionable benefits in terms of increasing VO_2 max, in this study at a given submaximal work rate it significantly reduced blood La and RPE values. In contrast to Bevegard's (5) study which revealed no difference in La during all exercise intensities between **L** and **A+L**, this study revealed a significant difference between La values during the work bouts. Ekblom and Goldbarg (14) proposed using as much muscle mass as possible, since they found for a given VO_2, RPE were statistically higher during **A** work than during **L** work. Perceived exertion was also higher during bicycling as compared to running and swimming. Gamberale (19) suggests that the higher the blood La level in relation to the VO_2, the greater will be the overall perception of effort in relation to HR. These studies support the notion that there are benefits to combined **A+L** exercise.

In conclusion, RPE and blood La were found to be significantly lower during **A+L** exercise as compared to **L** exercise, while HR, VO_2, and V_E remained similar, at the same absolute power output.

If someone exercises with the arms and legs, (s)he could produce less La and perceive the work as being easier; than if (s)he did the same work with the legs only. These results might have ramifications for exercise adherence and compliance, if they are incorporated into an exercise program.

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APPENDICES

APPENDIX A

INFORMED CONSENT FORM

You are invited to participate in a research study, the purpose of which is to compare ratings of perceived exertion and blood lactate levels for arm-and-leg versus leg-only work on the Schwinn Air-Dyne.

The study will take place on three separate days with the testing procedure lasting approximately sixty minutes each day. The first day you will perform a maximal exercise test, described in the following paragraph. The second and third days, by random ordering, both arm-and-leg and leg-only tests will be performed.

If you decide to participate, you will perform a maximal, graded exercise test to exhaustion on the Schwinn Air-Dyne at the beginning of the study. This test will be used to determine the appropriate work load for the subsequent arm-and-leg and leg-only workbouts. The work load for the next two exercise bouts will remain constant for the entire 40-minute period of the test. You will have the option of stopping the test at any point. The test will be stopped if symptoms such as excessive shortness

of breath or chest discomfort appear.

On the second and third test days you will perform an exercise bout at 75% of max (determined by the graded exercise test to exhaustion). Expired gases will be collected using the Rayfield system and a small amount of blood (0.10ml) will be taken at 10-minute intervals by sticking the fingertip with a lancet.

The risks involved with exercise include abnormal blood pressure responses, fainting, musculoskeletal injury, disorders of the heart, and in very rare instances heart attack. However, there is only a minor chance that serious complications will occur. In the event that physical injury occurs as a result of this research, the University of Tennessee does not automatically provide reimbursement for medical care or other complication. If physical injury is suffered in the course of research, or for more information, please notify the project director, John Lewis, at 974-5111 or the faculty sponsor, Dr. David Bassett, at 974-1284.

The information that is obtained in this study, such as your aerobic capacity, will be provided to you. Data from this study may be used in research reports or presentations; however, your

name and other identity will not be disclosed.

You are free to decide if you wish to participate in this study and can withdraw from the study at any time without prejudice. Before you sign this form please ask questions about any aspects of the study which are unclear to you.

AUTHORIZATION:

I, _____, have read the above and have decided to participate in the research project described above. My signature also indicates that I have received a copy of this consent form.

_____ _____

Participant's signature Date

_____ _____

Witness Date

Investigator: John E. Lewis

Address:

Dept of Human Performance and Sports Studies

College of Education

University of Tennessee-Knoxville

Room 334 HPER (615) 974-5111

APPENDIX B

INSTRUCTIONS FOR RATINGS OF PERCEIVED EXERTION

During the last fifteen seconds of each exercise stage you will be asked to give an estimate of how physically exerted you feel. As accurately as possible, you need to estimate the level of perceived exertion that you feel at the time we ask you. The level of perceived exertion means the total amount of exertion and physical fatigue that you feel, including all sensations and feelings of physical stress, effort and fatigue. Do not concern yourself with any one factor such as leg pain or shortness of breath, but try to concentrate on your total, inner feeling of exertion. You should give the most honest and objective score as possible. The following scale will be used to evaluate your perceived exertion:

6
7 very, very light
8
9 very light
10
11 fairly light
12
13 somewhat hard
14
15 hard
16
17 very hard
18
19 very, very hard
20

We will ask you to provide a number corresponding to the verbal anchors which best describe how you perceive the effort. For instance, a 6 would be equivalent to sitting at rest with no physical exertion, whereas a 20 would be a maximal, exhaustive effort which you could not sustain for very long.

APPENDIX C

Table C-1 Values for Heart rate for **L** and **A+L** exercise

		Time (min)				
	Subject	Rest	10	20	30	40
L	1	63	169	173	172	177
	2	86	154	161	166	167
	3	68	164	166	167	171
	4	82	151	165	171	173
	5	75	157	166	170	174
	6	98	174	175	180	180
	7	68	160	169	174	173
	8	99	168	173	175	178
	mean	79.88	162.13	168.50	171.33	174.13
	SD	13.77	7.99	4.84	4.52	4.16
A+L	1	62	166	170	173	176
	2	73	156	164	168	169
	3	66	161	164	168	169
	4	73	149	162	169	170
	5	62	155	162	168	172
	6	98	175	177	181	180
	7	68	160	167	172	171
	8	99	165	170	172	174
	mean	75.13	160.88	167.00	171.38	172.63
	SD	15.03	7.95	5.15	4.41	3.85

Table C-2 Values for Ventilation for **L** and **A+L** exercise

		Time (min)				
	Subject	Rest	10	20	30	40
L	1	10.94	78.59	83.77	87.90	86.96
	2	9.57	72.31	75.75	75.84	71.43
	3	8.03	63.26	66.15	69.37	65.59
	4	8.80	49.56	50.95	51.51	50.34
	5	8.64	67.78	71.71	74.18	80.03
	6	8.12	54.79	58.68	60.28	58.20
	7	9.14	62.62	62.79	66.90	66.21
	8	13.00	74.81	79.15	85.75	89.37
	mean	9.53	65.47	68.62	71.47	71.02
	SD	1.68	9.94	11.03	12.24	13.72
A+L	1	12.21	77.37	82.96	86.37	86.58
	2	8.96	73.84	75.02	75.37	70.28
	3	8.80	62.68	66.17	68.18	65.20
	4	9.26	49.09	49.09	50.56	50.67
	5	18.67	68.09	70.90	73.36	79.37
	6	8.64	53.93	57.40	59.18	57.31
	7	16.85	62.51	62.31	65.53	65.65
	8	16.46	74.43	80.96	84.71	89.62
	mean	12.48	65.24	68.10	70.41	70.59
	SD	4.22	10.12	11.68	12.20	13.74

Table C-3 Values for Oxygen uptake for **L** and **A+L** exercise

Time (min)

	Subject	Rest	10	20	30	40
	1	.43	3.13	3.25	3.29	3.40
	2	.38	3.09	3.25	3.25	3.25
	3	.33	2.48	2.58	2.54	2.65
	4	.32	2.54	2.70	2.70	2.76
L	5	.19	2.96	3.03	3.11	3.19
	6	.28	2.41	2.45	2.54	2.54
	7	.30	2.82	2.83	2.90	2.95
	8	.39	3.20	3.41	3.45	3.51
	mean	.33	2.83	2.94	2.97	3.03
	SD	.07	.31	.35	.35	.36
	1	.48	3.04	3.17	3.29	3.33
	2	.31	3.04	2.94	2.91	2.95
	3	.32	2.41	2.55	2.59	2.63
	4	.42	2.66	2.67	2.71	2.79
A+L	5	.39	2.94	2.99	3.05	3.12
	6	.29	2.49	2.53	2.55	2.59
	7	.36	2.91	3.01	3.08	3.04
	8	.43	2.84	2.91	2.96	2.99
	mean	.38	2.84	2.91	2.96	2.99
	SD	.07	.29	.31	.34	.32

Table C-4 Values for Lactate for **L** and **A+L** exercise

		Time (min)				
	Subject	Rest	10	20	30	40
L	1	.81	8.94	10.08	8.40	6.34
	2	3.06	7.16	7.46	6.87	5.67
	3	2.16	10.11	10.69	9.73	8.73
	4	1.26	2.80	4.15	4.01	3.89
	5	2.27	9.63	11.01	11.10	11.43
	6	3.61	8.89	9.90	9.28	7.48
	7	1.55	10.07	11.01	10.27	9.97
	8	2.46	9.65	11.71	11.16	9.20
	mean	2.15	8.41	9.50	8.85	7.84
	SD	.93	2.46	2.51	2.42	2.47
A+L	1	1.11	4.21	3.78	3.21	2.64
	2	3.09	9.12	9.46	9.01	8.20
	3	2.17	8.19	7.76	7.58	6.18
	4	1.56	3.78	3.90	4.00	3.10
	5	2.15	6.17	6.64	6.06	6.08
	6	3.85	6.13	6.11	6.03	6.11
	7	1.67	10.33	11.03	10.29	10.04
	8	1.44	3.58	3.10	3.44	3.12
	mean	2.13	6.44	6.44	6.20	5.68
	SD	.92	2.56	2.85	2.62	2.63

Table C-5 Values for Ratings of perceived exertion for **L** and **A+L** exercise

		Time (min)			
	Subject	10	20	30	40
L	1	18	19	19	20
	2	13	15	16	15
	3	13	17	18	19
	4	10	12	13	15
	5	11	12	13	15
	6	14	15	16	16
	7	13	14	15	16
	8	13	16	17	20
	mean	13.13	15.00	15.88	17.00
	SD	2.36	2.39	2.17	2.27
A+L	1	13	15	16	16
	2	13	14	16	15
	3	11	14	17	18
	4	10	13	14	14
	5	11	12	13	14
	6	14	14	14	15
	7	13	14	14	14
	8	12	14	16	16
	mean	12.13	13.75	15.00	15.25
	SD	1.36	.89	1.41	1.39

APPENDIX D

STATISTICAL ANALYSIS

Table D-1. Repeated Measures ANOVA for Oxygen uptake during **L** and **A+L** exercise

SOURCE	DF	SUM OF SQUARES	F	P
SUBJECTS	7	5.784		
MODE	1	.005	.208	.6621
ERROR	7	.177		
TIME	3	.277	26.582	.0000
ERROR	21	.073		
MODE*TIME	3	.005	.895	.4599
ERROR	21	.042		

Table D-2 Repeated Measures ANOVA for Heart rate during **L** and **A+L** exercise

SOURCE	DF	SUM OF SQUARES	F	P
SUBJECTS	7	1398.000		
MODE	1	22.563	3.211	.1163
ERROR	7	49.188		
TIME	3	1329.25	32.821	.0000
ERROR	21	283.5		
MODE*TIME	3	2.688	1.498	.2442
ERROR	21	12.563		

Table D-3 Repeated Measures ANOVA for Ventilation during **L** and **A+L** exercise

SOURCE	DF	SUM OF SQUARES	F	P
SUBJECTS	7	7629.013		
MODE	1	.568	.275	.6164
ERROR	7	2.222		
TIME	3	334.293	7.88	.001
ERROR	21	296.974		
MODE*TIME	3	1.082	1.295	.3023
ERROR	21	5.849		

Table D-4. Repeated Measures ANOVA for Ratings of perceived exertion during **L** and **A+L** exercise

SOURCE	DF	SUM OF SQUARES	F	P
SUBJECTS	7	129.859		
MODE	1	23.766	6.433	.0389
ERROR	7	25.859		
TIME	3	111.547	26.178	.0000
ERROR	21	29.828		
MODE*TIME	3	1.797	1.557	.2294
ERROR	21	8.078		

Table D-5. Repeated Measures ANOVA for Blood lactate during **L** and **A+L** exercise

SOURCE	DF	SUM OF SQUARES	F	P
SUBJECTS	7	223.041		
MODE	1	95.942	5.064	.0592
ERROR	7	132.619		
TIME	3	12.212	10.665	.0002
ERROR	21	8.016		
MODE*TIME	3	2.75	3.69	.0281
ERROR	21	5.217		

VITA

John Eugene Lewis was born on August 11, 1968 in Knoxville, Tennessee. Having always lived in Knoxville, he attended Carter Elementary School and graduated from Halls High School in May of 1986. He then entered The University of Tennessee at Knoxville in September of 1986 and completed work on his Bachelor of Science in Business Administration in August of 1990.

He reentered the Unversity in August of 1990 and began work on his Master of Science degree in Exercise Physiology in the Department of Human Performance and Sports Studies of the College of Physical Education.

After his graduation in May of 1992, he will begin work in a doctoral program in Higher Education and Sport Administration in August of 1992 at the University of Miami, Florida.