Prediction of Lower Extremity Lactate Levels in Exercising Muscle Utilizing Upper Extremity Sampling Sites

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ABSTRACT

Comeau, MJ, Adams II, TM, Church, JB, Graves, MM, Lawson, PM. Prediction of Lower Extremity Lactate Levels in Exercising Muscle Utilizing Upper Extremity Sampling Sites. JEPonline 2011:14(1):20-27. Getting an accurate measurement of blood lactate from working muscles is still debatable as to the most representative sampling site. The purpose of this study was to determine the relationship between lactate sampled from a non-exercising limb site in an effort to predict the blood lactate in an exercising limb in the field under non-laboratory settings. Eleven male subjects volunteered to participate in this study. After the 5 min warm-up period, subjects began pedaling at constant self-selected cadence between 80-90 rpm at a workload of 100 watts on a Velotron cycle ergometer. Each stage lasted 5 min with the intensity increasing by 50 watts in each subsequent stage. Once the subjects reached volitional fatigue, the foot was removed from the shoe, and blood samples were obtained from the great toe and the fingertip. Lactate was measured immediately post-exercise, and at 5 and 10 min post-exercise. A linear regression analysis was performed to evaluate the prediction of lower extremity lactate from the upper extremity sampling site (fingertip) immediately post-exercise, 5 min post-exercise, and 10 min post-exercise. The formulas were Y=5.97x + 1.282, Y = .765x + .782, and Y = .670x + .862, respectively. At 5 min post-exercise, 75% of the variance (R²=0.755) in toe lactate was shown in finger lactate. The blood lactate sampled from the finger 5 min post-exercise is the best place and time to indicate the lower extremity lactate in endurance athletes using primarily the lower extremity.

Key Words: Ergometry, Finger, Toe, Performance, Endurance
INTRODUCTION

Exercise testing is commonplace today among athletes and those interested in staying fit or achieving greater levels of fitness. Often times, invasive measures are used in an effort to better interpret test results or make appropriate changes to training programs. One such method (6) that has been around for approximately 50 years is the determination of lactate threshold via blood sampling, often referred to as onset of blood lactate accumulation (OBLA). Over the years, blood has been sampled from various places (ear lobe, finger, antecubital vein, and toe) in an effort to determine OBLA (3,5,8). However, blood lactate concentration varies depending on the sampling site. El-Sayed et al. (5) determined that subjects could sustain exercise for 30 min at the OBLA determined using plasma lactate from the finger, but could not maintain exercise for 30 min when using OBLA as measured from venous blood. Other studies (3,8), similar to this, have led to a disparity of exactly which sample site best determines blood lactate and ultimately the OBLA. A lactate equal to 4 mmol·L\(^{-1}\) has been commonly used as the OBLA. Although, it is widely known that there is variability in this value the more elite the athlete’s status (1).

Less invasive methods have also been used. The association between heart rate and OBLA has been used to set exercise session intensity and is still a common practice.(13) As El-Sayed et al. (5) presented, a heart rate associated with OBLA determined from finger samples compared to an OBLA determined from venous samples would underestimate exercise intensity. As a consequence, the athlete reduces or increases training intensity based on an OBLA that is established from a lactate that does not represent the environment of working muscle, which would negatively affect training intensities.

While mentioned nearly 30 years ago by Poortmans et al. (12), the role that other areas of the body play in the accurate determination of lactate has become an issue. Recently, the concept of inactive muscles storing lactate for later oxidation has been suggested in the literature (2,11). The exact mechanism of action is poorly understood as to why inactive muscle assumes this role and acts as a “passive sink” for lactate. As a result, when measuring lactate in the field or exercise setting, the accuracy of the lactate measurement may be influenced by the site selection. In situations where sample sites are associated with non-exercising muscle (e.g., sampling from the finger during cycling), it is possible the storage of lactate due to the sink phenomenon would directly influence the determined lactate. This finding presents a particular challenge in that it is not very feasible to sample blood from the toe of a runner or cyclist anymore than it would be to sample blood from the finger of a rock climber or rower. However, a few researchers have tried to determine an association between sampling sites using linear regression. Draper et al. (4) demonstrated a strong association via linear regression between blood lactate samples taken from the ear and finger in rock climbers. Garland and Atkinson (9) concluded that the toe is an acceptable sampling site in rowers compared to the ear lobe. In contrast, Feliu et al. (7) determined that lactate was significantly higher in the finger than the ear lobe. We have found similar differences in our lab when measuring plasma lactate post-exercise from the finger and great toe in cyclists. Therefore, close attention needs to be paid to sampling sites and their proximity to the non-exercising muscles.

Athletes can easily measure blood lactate when training with the use of portable lactate analyzers. Endurance athletes are encouraged to train at a level corresponding to OBLA in an effort to improve endurance performance (14). Subsequently, during and after the training session, the athlete may sample blood from an easily accessible area (finger) in an effort to determine the lactate concentration in the blood and ultimately adjust training intensity up or down based off of this value (10). However, Poortmans et al. (12) demonstrated that very shortly after exercise, inactive muscles stop serving in a passive sink capacity and release lactate back into the blood. This was
demonstrated with non-significant differences between arterial and venous lactate after the 5th min post-exercise. Therefore, if an athlete (e.g., runner) waits for any length of time after exercise to sample blood lactate from the finger, which is an easily accessible site, then the blood lactate measured may be already changing from immediate post-exercise levels.

The purpose of this study was to determine the relationship between blood lactate sampled from a non-exercising limb site (fingertip) in an effort to predict the blood lactate in an exercising limb using common assessment techniques post-exercise, much in the same way an athlete would assess lactate in the field under non-laboratory settings.

**METHODS**

**Subjects**

Eleven male subjects from a local cycling club volunteered to participate in this study. The group’s mean ± SD for age, weight, height, and percent body fat were 39.91 ± 8.29 years, 81.32 ± 13.41 kg, 178.49 ± 7.78 cm, and 15.82 ± 6.06 %, respectively. All subjects were cyclists with at least 6 months of cycling experience prior to testing, and all were currently participating in cycling on a regular basis. The subjects were instructed not to exercise in the 24 hours prior to testing. Additionally, they were asked not to consume caffeine for 12 hours prior to testing.

This study was approved by the Internal Review Board of Arkansas State University. Before any testing occurred, all subjects read and signed an informed consent. They were pre-screened using a health history questionnaire and determined to be healthy, without cardiovascular, pulmonary, or orthopedic limitations. Subjects also completed a 3-day food log prior to the testing session to ensure a normal diet comprised of approximately 60% carbohydrates, 30% fat, and 10% protein was being consumed.

**Procedures**

Once the subjects reported to the Human Performance Laboratory for testing, they changed into their cycling attire. The subjects’ height and weight were measured using an electronic scale (Befour, Inc., Saukville, Wisconsin) and a measuring tape. Percent body fat was determined using the 3-site skinfold method. The sites were assessed (chest, abdomen, and thigh) according to the American College of Sports Medicine’s guidelines using Lange skinfold callipers (Cambridge, Maryland). The subjects then rested in a supine position on a padded table for 5 min. Following the 5 min rest, initial blood samples were drawn from the fingertip of the subjects’ non-dominant hand and the great toe on the ipsilateral side. The toe sample site was covered with a Band-Aid®, then the subjects put their socks and shoes back on to simulate actual riding conditions during the ride.

After mounting the Velotron cycle ergometer (RacerMate, Seattle, Washington), the bicycle seat height was adjusted so that the subject’s leg was slightly bent when the pedal was in the bottom, dead-center position with knee over the top of the foot. During the 5 min warm-up at a self-selected pace and resistance, the subjects were familiarized with the shifting procedures for the bicycle and made aware of the revolutions per min (rpm) reading on the computer monitor. After the 5 min warm-up, the subjects began pedaling at constant self-selected cadence between 80-90 rpm at a workload of 100 watts. The Velotron was programmed to ensure a constant 100 watt power output regardless of any variation in pedal cadence. Each stage lasted 5 min. The intensity was increased by 50 watts in each subsequent stage over the previous stage until volitional fatigue or the subjects could no longer maintain at least 80 rpm.

Once the subjects reached volitional fatigue, the foot was removed from the shoe and sock, and blood samples were obtained from the great toe and fingertip. Samples were taken at approximately
the same time from both sites and the stop time for the subjects was less than 2 min for each blood draw. Then, the subjects placed their foot on top of their shoe and continued a cool-down ride at 50 W with a cadence between 80 and 90 rpm. The subjects completed this cool-down for 25 min or until they were ready to discontinue with blood samples being drawn from the great toe and the fingertip every 5 min for the first 10 min of the cool-down.

Blood samples were taken from the finger during the testing phase of the ride to substantiate that the subjects had indeed met the 4 mmol·L⁻¹ lactate associated with OBLA. Blood samples were not collected from the great toe during the ride. Blood lactate levels were analyzed using two YSI 1500 Sport lactate analyzers (Yellow Springs Instruments, Yellow Springs, Ohio). Prior to subject testing, inter-machine reliability was determined based on blood samples from five different subjects (intraclass correlation coefficient [ICC] r = .9940). Blood samples were drawn from the finger using an Autolet II spring loaded lancing device (Owen Mumford, Oxford, England) containing Unilet disposable lancets (Owen Mumford, Oxford, England) and Autolet platforms (Owen Mumford, Oxford, England). Blood samples were drawn from the great toe using shera-sharp long-point lancet (Propper, Long Island City, New Jersey). All blood samples were drawn into heparinized capillary tubes (Clay Adams, Parsippany, New Jersey). All sample sites were cleaned with sterilized alcohol pads containing 70% isopropyl alcohol. Constant pressure was then placed proximal to the sample site and the site was pierced with the appropriate device. The first drop of blood was wiped clean and the subsequent blood drops were collected and analyzed immediately. Time of collection ranged from 45 to 90 sec. The same YSI Sport lactate analyzer was used to analyze all blood samples from the same site for a given subject. The lactate analyzer used to analyze samples from a specific site was alternated with each subject to correct for the slight inter-machine variability.

Statistical Analyses
Descriptive statistics (mean ± SD) were calculated for subject characteristics (age, weight, height, and percent body fat). A bivariate linear regression analysis was performed to determine if lactate sampled from an upper extremity site (finger) immediately, 5 min post-exercise, and 10 min post-exercise could be used to predict lactate in lower extremity muscles. The data were analyzed using SPSS version 17.0 (SPSS, Inc., Chicago, IL).

RESULTS
Descriptive statistics (mean ± SD) for lactate from the toe and the finger at each sampling time are in Table 1. A linear regression analysis was conducted to evaluate the prediction of lower extremity lactate from an upper extremity sampling site (finger). The scatterplot for finger plasma lactate and toe plasma lactate immediately post-exercise, 5 min post-exercise, and 10 min post-exercise are shown in Figures 1-3. The regression equation for predicting toe lactate from finger lactate immediately post-exercise, 5 min post-exercise, and 10 min post-exercise are Y = .597x + 1.282, Y = .765x + .782, and Y = .670x + .862, respectively.

Table 1. Plasma [La⁻] (mmol·L⁻¹) at each sampling site (Mean ± SD).

<table>
<thead>
<tr>
<th></th>
<th>Immediately Post-ex</th>
<th>5 min Post-ex</th>
<th>10 min Post-ex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finger</td>
<td>7.72 ± 1.41</td>
<td>6.43 ± 1.71</td>
<td>5.48 ± 1.67</td>
</tr>
<tr>
<td>Toe</td>
<td>5.89 ± 1.42</td>
<td>5.70 ± 1.51</td>
<td>4.53 ± 1.40</td>
</tr>
</tbody>
</table>
The 95% confidence intervals (Table 2) for both 5 min post-exercise and 10 min post-exercise do not contain the value of zero and, therefore, toe lactate is significantly related (\(p = 0.001\) and \(p = 0.004\), respectively) to finger lactate.

**Table 2. 95% Confidence Intervals for each sample time.**

<table>
<thead>
<tr>
<th></th>
<th>Immediately Post-ex</th>
<th>5 min Post-ex</th>
<th>10 min Post-ex</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-.010</td>
<td>1.204</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.437</td>
<td>1.094</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.279</td>
<td>1.060</td>
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</tbody>
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As shown in Figure 2 at 5 min post-exercise, 75% of the variance (\(R^2=0.755\)) in toe lactate was shown in finger lactate; whereas, the variance immediately post-exercise (Figure 1) and at 10 min post-exercise (Figure 3) was less and would make interpretation of finger lactate more difficult at these sampling times. The 95% confidence interval immediately post-exercise does contain the value of zero and therefore, toe lactate was not significantly related (\(p = 0.053\)) to finger lactate at that time.

**Figure 1. Scatter plot for immediately post-exercise [La^-]**

**DISCUSSION**

With the issues of sample site, the function that inactive muscles play during exercise, and the subsequent practices of monitoring post-exercise lactate for exercise intensity determination or adjustment, the findings of this study allow for a better understanding of how to use the data. Currently, athletes sample blood immediately after a training bout to determine lactate to judge the intensity of the exercise session and ultimately whether intensity needs to be changed. Poortmans et al. (12) demonstrated that immediately after exercise lactate is released from inactive muscles back into the circulation within 5 min post-exercise. We have observed significant decreases in lactate immediately post-exercise compared to 5 min post-exercise when sampling from the finger and toe in cyclists (unpublished data). As shown in Figure 2, the highest level of association post-exercise in predicting lower extremity lactate from an upper extremity site would be to sample at 5 min post-exercise compared to immediately post-exercise or at 10 min post-exercise.
Dassonville et al. (3) sampled from the finger, forearm, and ear during upper and lower extremity cycle ergometry and treadmill running. They found similar results to Draper et al. (4). However, they were looking at the difference of sampling from upper extremity sites and the ear during lower extremity exercise while having no reference to the lactate in the lower extremity. Therefore, we cannot conclude from either data set that the ear is a better location to sample than the finger without having actual lactate values sampled from the toe. Forsyth and Farrallay (8) sampled lactate from the finger, toe, and ear in rowers immediately after exercise at two different workloads, but found no significant differences in lactate between sampling sites. They also reported moderate non-significant
correlations between the toe and fingertip at workloads of 75% and 90% of max heart rate (r = 0.79 and r = 0.46, respectively). While the correlations are similar to our findings immediately post-exercise, rowing is considered to be an exercise mode that involves both the upper and lower extremity. Therefore, comparison to a lower extremity exercise mode such as cycling or running doesn’t allow for a fair analysis.

Finally, Toutou et al. (15) showed that endurance athletes recovered quicker and removed more lactate when compared with sprinters. Due to the fact that mostly endurance related athletes use this type of training, it is reasonable to conclude that by using cyclists, the data closely represent a similar response that would be seen in other endurance type athletes regardless of the mode of exercise. Thus, the findings of this study suggest that the use of non-active sample sites may influence the accuracy of lactate measurements. As a result, given the challenge of sampling from the toe, non-active site measurements should be corrected for accuracy by being fitted to the recommended regression equation at the appropriate time.

CONCLUSIONS

The blood lactate sampled from the finger 5 min post-exercise is the best site and time to indicate the lower extremity lactate in endurance athletes who are primarily using the lower extremity.

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