Isokinetic Exercise Velocities and Blood Lactate Concentrations in Strength/Power and Endurance Athletes

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ABSTRACT

We examined the effect of different isokinetic exercise velocities on blood lactate concentration in strength/power (SP) and endurance (EN) athletes. Ten SP athletes (96.8 ± 16.2 kg) and 10 EN athletes (70.1 ± 9.4 kg) performed 20 maximal isokinetic knee extensions and flexions at 3 velocities (1.05, 2.09, and 5.23 rad·s⁻¹) on an isokinetic dynamometer. Trials were randomly assigned and separated by at least 48 hours. Capillary blood samples (150 μl) were collected before and 2, 4, and 6 minutes after exercise. Significant differences were observed for blood lactate concentrations among velocities for SP athletes with postexercise values at 1.05 rad·s⁻¹ (2 minutes, 6.64 ± 0.46; 4 minutes, 6.87 ± 0.50; 6 minutes, 6.34 ± 0.39 mmol·L⁻¹) and 2.09 rad·s⁻¹ (2 minutes, 6.49 ± 0.30; 4 minutes, 6.57 ± 0.34; 6 minutes, 6.67 ± 0.45 mmol·L⁻¹) higher than 5.23 rad·s⁻¹ (2 minutes, 5.40 ± 0.30; 4 minutes, 5.46 ± 0.33; 6 minutes, 5.40 ± 0.32 mmol·L⁻¹). No significant difference was observed in blood lactate concentrations among velocities for EN. The postexercise blood lactate concentrations were significantly higher for SP athletes compared with EN athletes at each velocity; however, this difference was eliminated when corrected for body mass. Total work was significantly greater for SP athletes compared with EN athletes at each velocity. Total work performed by both SP and EN athletes was significantly higher at 1.05 and 2.09 rad·s⁻¹ compared with 5.23 rad·s⁻¹. The data indicate that SP athletes will produce the highest blood lactate concentrations when using slower isokinetic velocities, which may be due to the total amount of work performed.

Key Words: anaerobic exercise, training, metabolism


Introduction

The use of isokinetic exercise as a rehabilitation modality and resistance training mode has recently increased in popularity (11). Past research on isokinetic exercise has focused on the effects of velocity-specific exercise on peak torque or peak power changes during exercise (14), establishing muscle force–velocity relationships (2, 9, 10, 15, 16), and strength improvements through training (3, 13, 22). Isokinetic exercise offers maximal resistance through the full range of motion. Because of this different isokinetic exercise velocities may result in different metabolic responses in the muscle. To maximize the effectiveness of isokinetic exercise in training, it is necessary to understand how different contraction velocities affect energy production. Specifically, it has not been sufficiently demonstrated what relationship isokinetic exercise velocity has on the formation of lactate in the contracting muscle. Douris (5) contended that there was a significant elevation in blood lactate concentration with an increasing isokinetic exercise velocity. However, differences in the type of athlete tested (i.e., strength/power [SP] vs. endurance [EN] athlete) and the amount of total work performed were parameters not considered (5).

The amount of lactate that is produced during isokinetic exercise may depend on the contraction velocity and the type of athlete being tested. Tesch and Karlsson (19) have shown that certain motor unit distribution patterns exist among different types of well-trained athletes. These fiber-type characteristics may account for differences in the amount of lactate that is formed during exercise for specific types of athletes. Highly proficient EN athletes demonstrated a predominance of slow-twitch motor units that were highly aerobic in nature (19). Conversely, top-level SP athletes have displayed a higher percentage of fast-twitch motor units that have a greater tendency to rely on anaerobic metabolism (19). Athletes with a predominance of fast-twitch motor units have been shown to produce twice as much lactate during maximal exercise compared with athletes with a predominance of slow-twitch motor units (8).

It is of interest to determine the most appropriate exercise velocity to use when attempting to train the anaerobic energy system via isokinetic exercise. Differ-
ences between athletes who are trained for EN events and those who are trained for SP power events may result in differences in blood lactate concentration during isokinetic exercise. This may be due to the fact that certain metabolic characteristics, which predominate in either type of athlete, may influence lactate production during this mode of exercise. The purpose of this study was to examine the effect of slow and fast isokinetic exercise velocities on blood lactate concentration in both SP and EN athletes. Furthermore, we wanted to determine if differences exist in blood lactate concentration between SP and EN athletes as they perform isokinetic exercise at different contraction velocities.

Methods

Subjects

Ten men SP athletes and 10 men EN athletes voluntarily participated in the investigation. The physical characteristics of the athletes were as follows: age (SP athletes, 23.1 ± 3.4 years; EN athletes, 21.8 ± 3.5 years); height (SP athletes, 180.8 ± 5.0 cm; EN athletes, 180.1 ± 5.3 cm); and body mass (SP athletes, 96.8 ± 16.2 kg; EN athletes, 70.1 ± 9.4 kg). All SP athletes were college football players involved in rigorous resistance-training exercise at least 3 d·wk⁻¹, while the EN athletes were college cross-country team members running at least 68 km·wk⁻¹. Both the SP and EN athletes were in continuous training for at least 6 months before testing. After receiving a verbal explanation of the procedures, all subjects provided written informed consent in accordance with university guidelines for human experimentation.

Design

The athletes reported to the laboratory on 4 separate occasions. During the initial session each athlete was allowed to familiarize himself with the Merac isokinetic dynamometer (Universal Gym Equipment, Cedar Rapids, IA) and the 3 exercise velocities used during testing. The 3 isokinetic velocities were 1.05 rad·s⁻¹, 2.09 rad·s⁻¹, and 5.23 rad·s⁻¹. All testing sessions were conducted at approximately the same time of day, with each session separated by at least 2 days but not more than 7 days. The exercise velocities were randomly assigned from a counterbalanced design. Athletes were instructed not to participate in any physical exercise on the day of testing and to maintain the same dietary habits during the investigation.

Testing

Each athlete reported to the laboratory in a 3-hour postabsorptive state. On entering the laboratory, the athlete was given a 10-minute rest while seated on the chair of the isokinetic dynamometer. With the hips at approximately 110° of flexion, belts were fastened around the waist, thigh, and lower leg. The axis of the knee joint was aligned with the axis of rotation of the lever arm of the isokinetic dynamometer. The range of motion was 90°. Only the dominant leg was tested. Before exercise the athlete’s hand was placed in a heating chamber at a temperature of 50–60°C for 10 minutes to maximize blood flow through the capillaries of the hand. For blood collection the hand was removed from the heating chamber and a 150-μl sample was obtained via fingerstick procedure.

Following the resting blood sample collection, the speed selector of the isokinetic dynamometer was adjusted to the randomly assigned velocity for that testing session. The athlete then performed 20 maximal knee extensions and flexions in a continuous manner. The approximate time to complete the 20 repetitions was 60 seconds for 1.05 rad·s⁻¹, 30 seconds for 2.09 rad·s⁻¹, and 12 seconds for 5.23 rad·s⁻¹. The number of repetitions selected was based on typical training and clinical rehabilitation protocols. Immediately following exercise, the athlete placed his hand back into the heating chamber. Additional 150-μl capillary blood samples were collected 2, 4, and 6 minutes after exercise. Peak blood lactate concentrations have been shown to occur within this time frame in response to maximal intensity exercise (6, 8). The preexercise and postexercise blood samples were stored in Yellow Springs Instrument (YSI) Total Blood Lactate tubes (YSI Inc, Yellow Springs, Ohio) until analysis. All blood samples were analyzed in duplicate within 48 hours of collection using a calibrated YSI 1500 Sport L-lactate Analyzer. The duplicate sample values were averaged for statistical analysis. The coefficient of variation was less than 3.3% for all lactate analyses.

Data Analysis

A 3-way (group × velocity × time) analysis of variance (ANOVA) with repeated measures on the time variable was used to examine differences between groups for blood lactate concentrations and the blood lactate concentrations expressed relative to body mass. Paired t-tests were used to determine significant differences among the means. A 2-way ANOVA and paired t-tests were used to determine differences in total work performed at the 3 velocities between and within each group. Significance was set at \( p \leq 0.05 \) for all testing. All values are reported as mean ± SD.

Results

There were no significant differences between the SP and EN athletes for age and height. The SP athletes had significantly greater body mass than the EN athletes.

Significant differences in blood lactate concentrations were observed for athlete type, exercise velocity, and measurement time. Table 1 illustrates the blood lactate concentrations for the athletes performing max-
imal isokinetic leg exercise at each velocity. There were no significant differences in preexercise blood lactate concentrations between the SP and EN athletes before the isokinetic exercise. For each isokinetic velocity the postexercise blood lactate concentrations were significantly higher in the SP athletes compared with the EN athletes. When blood lactate concentration was expressed per kilogram body mass, there were no significant group effects; however, there were still significant differences among the exercise velocities and with the measurement times. The blood lactate concentration:body mass ratio data are not shown.

For the SP athletes the postexercise blood lactate concentration was significantly higher following isokinetic exercise at 1.05 and 2.09 rad·s⁻¹ compared with isokinetic exercise at 5.23 rad·s⁻¹. There was no significant difference in postexercise blood lactate concentrations among the 3 exercise velocities for the EN athletes. There was a significant increase in blood lactate concentrations from preexercise to postexercise for each isokinetic exercise velocity for both the SP and EN groups. The 2-, 4-, and 6-minute values were all significantly higher than the preexercise value. There were no significant differences among the postexercise blood lactate concentrations for either the SP or EN group regardless of isokinetic exercise velocity. Estimation of the statistical power associated with blood lactate concentrations and blood lactate concentration:body mass ratio revealed varying levels of power. For the blood lactate concentration analysis, power ranged 0.69–1.00, and for the blood lactate concentration:body mass ratio power ranged 0.26–1.00.

The total work performed for the SP and EN athletes for each isokinetic velocity is shown in Table 2. For both groups of athletes the amount of work performed at 1.05 and 2.09 rad·s⁻¹ was significantly higher than 5.23 rad·s⁻¹. The SP athletes performed significantly more total work than the EN athletes at each exercise velocity.

### Table 1. Blood lactate response to isokinetic leg exercise in strength/power (n = 10) and endurance (n = 10) athletes (mean ± standard deviation).*

<table>
<thead>
<tr>
<th>Athlete</th>
<th>Velocity (rad·s⁻¹)</th>
<th>Preexercise</th>
<th>Postexercise</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 min</td>
</tr>
<tr>
<td>SP</td>
<td>1.05</td>
<td>1.95 ± 0.71</td>
<td>6.64 ± 1.44 B</td>
</tr>
<tr>
<td>EN</td>
<td>1.59 ± 0.44</td>
<td>4.28 ± 1.29 C</td>
<td>4.33 ± 1.48 C</td>
</tr>
<tr>
<td>SP</td>
<td>2.09</td>
<td>1.80 ± 0.55 A</td>
<td>6.48 ± 0.95 B</td>
</tr>
<tr>
<td>EN</td>
<td>1.54 ± 0.69</td>
<td>4.36 ± 1.52 C</td>
<td>3.97 ± 1.34 C</td>
</tr>
<tr>
<td>SP</td>
<td>5.23</td>
<td>1.71 ± 0.47 A</td>
<td>5.39 ± 0.95 D</td>
</tr>
<tr>
<td>EN</td>
<td>1.49 ± 0.65</td>
<td>3.67 ± 0.79 C</td>
<td>3.75 ± 0.87 C</td>
</tr>
</tbody>
</table>

*Significant differences between and within groups (p < 0.05). Values with different letters are significantly different. SP = strength/power athlete; EN = endurance athlete.

### Table 2. Total work for strength/power (n = 10) and endurance athletes (n = 10) performing isokinetic exercise at 3 different contraction velocities (mean ± standard deviation).

<table>
<thead>
<tr>
<th>Velocity</th>
<th>Total work (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.05 (rad·s⁻¹)</td>
<td>6.84 ± 1.8*</td>
</tr>
<tr>
<td>2.09</td>
<td>7.24 ± 1.6*</td>
</tr>
<tr>
<td>5.23</td>
<td>5.27 ± 1.1**</td>
</tr>
</tbody>
</table>

*Significant difference between the strength/power and endurance athletes (p ≤ 0.05); **Significant difference within each group, with the 5.23 rad·s⁻¹ value less than the 1.05 rad·s⁻¹ and 2.09 rad·s⁻¹ values (p ≤ 0.05).

### Discussion

During training or rehabilitation the enhancement of energy production is critical to athletes performing high-intensity work. The relationship between different isokinetic exercise velocities and muscle and blood lactate concentration has not been completely investigated. Douris (5) contended that when attempting to train the anaerobic energy system via isokinetic exercise faster contraction velocities should be used. Data from Douris (5) indicated that isokinetic leg exercise at 5.23 rad·s⁻¹ and 2.09 rad·s⁻¹ would result in significantly greater lactate production than exercise at 0.52 rad·s⁻¹. Data from the present investigation do not support the findings of Douris (5). In the present study the highest blood lactate concentrations were observed during exercise at 1.05 and 2.09 rad·s⁻¹ by the SP athletes. Additionally, for the EN athletes, there were no differences among the exercise velocities for blood lactate concentrations. Differences in the results of the present study and those reported by Douris (5) may be partially explained by 2 factors: the total amount of work performed during exercise and the type of
long-term training the subjects performed before testing.

The amount of muscle lactate formation and subsequent blood lactate concentration during exercise is a function of a multitude of factors, including exercise intensity, total work performed, and total body mass (1). During maximal-intensity exercise the amount of lactate formed will be a function of the total work performed (12). This explains in part the data from the present study and why our results are different from previously reported data (5). The total work performed by the SP athletes was significantly higher than the EN athletes at each contraction velocity. This contributed to the blood lactate concentrations for the SP athletes being greater than the EN athletes. A closer examination of the data reveals that the SP athletes performed more total work at 1.05 and 2.09 rad·s⁻¹ when compared with 5.23 rad·s⁻¹. This resulted in higher blood lactate concentrations at those velocities for the SP athletes. Although there were higher total work values at 1.05 and 2.09 rad·s⁻¹ compared with 5.23 rad·s⁻¹ in the EN athletes, this did not result in higher blood lactate concentrations. Examination of the data from Douris (5) revealed that significantly greater amounts of work were performed at the faster contractions’ velocities, which likely contributed to the higher blood lactate concentrations and the conclusions drawn from that investigation. When expressed per kilogram body mass, the blood lactate concentration differences between the SP and EN athletes were eliminated. Shepard et al. (17) have demonstrated that lactate formation is a function of the total volume of musculature involved in the contraction process. Although active muscle volume was not measured in the current study, the crude ratio of blood lactate concentration to total body mass does support the work of Shepard and colleagues.

Another factor that may influence the blood lactate response to isokinetic exercise is the type of athlete tested. A contributing factor to the amount of lactate produced during exercise by different types of athletes is the type of lactate dehydrogenase (LDH) isozyme present in the contracting muscle fiber (7). Enzyme kinetic studies have identified a spectrum of isozymes for LDH (4). The isozyme for LDH found specifically in cardiac and slow-twitch muscle (LDHₐ) favors the conversion of lactate to pyruvate, whereas the LDH isozyme found in fast-twitch muscle (LDHₘ) favors the conversion of pyruvate to lactate (18). Previous research has demonstrated that total LDH activity and LDHₘ activity is higher in fast-twitch fibers compared with slow-twitch fibers (20, 21). Furthermore, it has been demonstrated that muscle fiber types vary in athletes who train differently and that SP athletes tend to have a higher percentage of fast-twitch fibers compared with EN athletes, who have a higher percentage of slow-twitch fibers (19). The combination of these 2 factors (LDH isozyme type and percentage of fast-twitch and slow-twitch fibers) may also have contributed to the different blood lactate responses obtained in the present investigation.

The data from the present investigation indicate that higher blood lactate concentrations will be obtained during slower isokinetic velocities in SP athletes, which is likely due to the greater amount of work performed. The EN athletes did not experience any significant differences among the exercise velocities despite differences in total work performed. Future research should examine the blood lactate response to different isokinetic exercise velocities when total work is held constant.

**Practical Applications**

The data from the present investigation have important implications for the strength and conditioning coach who is designing a training or rehabilitation program for athletes. The type of athlete being trained must be considered when selecting an appropriate isokinetic contraction velocity for training the anaerobic energy system. Individuals training for SP should use slower isokinetic velocities when attempting to enhance the anaerobic energy system. The selection of an inappropriate isokinetic contraction velocity may result in nonspecific adaptations to the muscle of the athlete being trained.

**References**


