Blood Lactate Response to Weightlifting in Endurance and Weight Trained Men

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ABSTRACT

The purpose of this study was twofold: (1) to determine whether weight trained men accumulate greater amounts of blood lactate when working with the same relative resistance as untrained and endurance trained men, and (2) to examine the relationship between the lactate response to weightlifting, external work and weightlifting intensity. Fifteen men were divided into three groups according to training history, and participated in three sets of exhaustive weightlifting (60, 70 and 80 percent of 1 RM), each of which ended in volitional fatigue. Capillary blood was drawn and analyzed for lactate at rest, immediately after each set and every two minutes of recovery to minute 15. External work and intensity were estimated at each set, and total work and intensity were calculated for the entire protocol.

The mean lactate response of the weight trained men at 80 percent 1 RM was 21 percent and 30 percent greater than the untrained and endurance trained men, respectively. All groups were similar at the 60 percent and 70 percent exercise intensity. Each group increased blood lactate levels in a linear fashion as exercise intensity increased from the first to the last set. The weight trained men produced greater intensities and external work at each set and for the total workout. Minimal lactates were seen at two minutes post-exercise in all groups. Lactates were related to external work and intensity, with the highest correlation (r = 0.66) between lactate and average intensity of the workout. This study produced an increased absolute blood lactate response in weight trained individuals who were heavier and thus were likely utilizing a larger contracting muscle mass. Total relative work was the only predictor that failed to correlate significantly with lactate, possibly indicating an equal lactate production per kilogram of body weight. Also, the greater external work is probably a reflection of the larger muscle mass of the weight trained group.

KEY WORDS: Anaerobic, resistance exercise.

Introduction

The accumulation of blood lactate during traditional forms of weightlifting has previously been thought to be minimal (7, 10), with this effect due mainly to the greater demands placed on the phosphagen energy system. Recently, however, it has been shown that weightlifting may place a heavy burden on anaerobic glycolysis, resulting in a large blood lactate accumulation (11, 19, 20). This response is predicated on the intensity of lifting (9), which may be thought of as the interaction between total load, repetition cadence and rest time between sets (3, 18, 20).

Weightlifting performed in such a manner as to activate the anaerobic glycolytic system may be expected to produce training adaptations leading to a greater utilization of this metabolic pathway and/or neural adaptations which, during maximal, high intensity lifting, may result in more selective recruitment of the type IIb muscle fiber. These training adaptations are thought to involve either an increase in the concentration of glycolytic enzymes or their activity and/or possibly a conversion of the type
Ilα fast-oxidative muscle fiber to the type IIB fast-glycolytic muscle fiber (3, 13, 19). Weight trained persons may, therefore, have a greater potential to accumulate blood lactate during weightlifting when compared to non-weight trained individuals. Stone et al. (19) tested this hypothesis using absolute resistances and found that weight trained subjects produced less blood lactate when exercising with the same submaximal poundages as the untrained subjects. However, the untrained subjects fatigued earlier than the trained subjects, which resulted in a far greater amount of exercise performed by the trained group and thus a higher maximal blood lactate level was achieved. The lower submaximal blood lactate response by the trained group was probably a reflection of differences in strength which would allow them to function at a lower percentage of maximum at each absolute resistance. A smaller percentage of the total available motor units may have been activated by the experienced lifters in comparison to novice lifters, resulting in less blood lactate accumulation at each absolute resistance (19). However, in the case of bodybuilders, who may be considered to be a separate subclass of resistance-trained individuals, this apparent difference may be due to the ability to clear lactate because of a presumed greater capillary density. However, this does not appear to be true of muscle strength trained as opposed to muscle endurance trained groups (21).

The hypothesis that greater lactate accumulation occurs in weight trained subjects is still viable, however, owing to the metabolic and neural specificity of training. Sale et al. (15) have pointed out that strength training results in an ability to recruit additional motor units during maximal voluntary effort. Conversely, untrained subjects may either be unable to activate their muscles fully at maximum, especially if multi-joint movements are used (15), or may be unable to raise the firing rate sufficiently to activate the type IIB units (14). In either case, this will probably result in a reduced blood lactate output by the untrained performers, since it is known that the glycolytic type IIB fibers are probably responsible for most of the lactate production (8).

The present investigation proposes to examine the hypothesis that due to the neural and metabolic specificity of weight training, trained lifters will accumulate more blood lactate when performing a series of weightlifting sets to exhaustion using relative resistances (percent 1 RM). The protocol used in the present investigation was designed to test maximal muscle endurance capacity, which would then assure a stress level of sufficient intensity to generate a significant blood lactate response. The objectives of this study were to determine: (1) the lactate response to relative resistance weightlifting in untrained and differentially trained men, and (2) the relationship between intensity of exercise, external work and the lactate response.

Methods

Subjects

Eighteen male volunteers participated in this investigation. Of these, three subjects failed to complete the data collection period because of adverse side effects following the weightlifting protocol (syncopal episodes and profound bradycardia). The remaining 15 subjects completed the study. Five untrained (UT) men were sedentary during the past year except for occasional light recreational activities. Five endurance trained (ET) men averaged five years of competitive experience at > 56.4 kilometers per week in training. Five weight trained (WT) subjects averaged three years of training at greater than 20 hours per month. All subjects were recruited from the campus of the University of Southern Mississippi and the surrounding community, and subsequently signed an institutional informed consent for participation.

Protocol

The 1 RM method described by Stone and O'Bryant (18) was used to determine maximal leg press strength (Universal Gyms Inc., Cedar Rapids, Iowa). At this time the subjects were informed of the measurement procedures to follow. Subjects were instructed to maintain their normal diet and activity pattern during the course of the study. During the 1 RM and experimental procedures, subjects' hip and knee angles were equated to 65 to 69 degrees and 88 to 90 degrees, respectively, while seated on the adjustable seat of the weight machine. Values for hip and knee angles between groups were nonsignificant, as confirmed by a one-way ANOVA. This was an attempt to control for mechanical advantages between groups and subjects. There was a minimum of three days rest between the 1 RM test and the experimental procedure.

Upon reporting to the laboratory for the experimental treatment, a 15-minute period of rest was followed by baseline determination of blood lactate. The exercise treatment consisted of a three-set series of weight lifting at 60, 70 and 80 percent of 1 RM, respectively. Each set was performed to voluntary exhaustion after strong verbal encouragement to stimulate glycolytic production of lactate to its fullest potential for this type of exercise and/or to potentiate sufficient accumulation of this metabolite. Voluntary exhaustion has been used elsewhere (19) as an experimental procedure. The lifting cadence was controlled verbally by an experimenter and by an auditory/visual metronome set at a 1:1 second ratio.
(two seconds per repetition) for concentric and eccentric phases of contraction. During each repetition the weight stack was required to be touched upon lowering, without coming to a complete stop. During the performance of each repetition the subjects were required to progress from the eccentric phase of lifting to the concentric without any time for rest at the full press (knee extended) position. Each set was followed by a two-minute period of rest while the subject maintained the same sitting position as during the lifting phase (i.e., feet remained elevated on the foot pads). Following the exercise period, recovery values were recorded at two and five minutes, and every two minutes thereafter. The subjects remained seated with legs elevated during the first seven minutes of recovery, at which time they were allowed to lower their legs for the remainder of the fifteen minutes of recovery. This procedure was necessary for subject comfort, as there tended to be a high incidence of gluteal cramping.

Measurements

Estimated external work was determined at each relative resistance as the weight lifted times the number of repetitions times the vertical displacement of the weight stack. The estimated relative work was the estimated external work divided by the subject's body weight. Total external work was determined for the protocols as the total weight lifted (sum of the weight stack at each relative resistance times the repetitions at each relative resistance) times the vertical displacement. Total relative work was the total external work divided by the subject's body weight.

Weightlifting intensities were calculated as follows:

\[
\text{Exercise Intensity (W) = External Work + Set Time} \\
\text{Average Intensity (W) = Mean External Work + (Mean Rest Time + Mean Set Time)} \\
\text{Total Intensity (W) = Total External Work + Total Exercise Time}
\]

where exercise intensity is the intensity of each set of exercise during the protocol and is expressed as the external work for each set divided by the time to complete the set (two seconds per repetition times the number of repetition performed); average intensity is the mean intensity of the protocol and is expressed as the mean external work divided by the sum of the mean rest time (two minutes) and average time to complete each set; and total intensity is the total external work divided by the total exercise time (total rest time + total set time). Average intensity and total intensity are expressions of the degree of difficulty of the entire three-set protocol and, therefore, rest time between sets is used as a variable in these equations. Exercise intensity is an expression of the degree of difficulty of each set and, therefore, rest time between sets is not used. In all calculations, intensity of exercise is the estimated power output (in watts), and is considered to be proportional to the rate of energy utilization (18).

Capillary blood samples were obtained at the end of the resting phase and immediately following each set of exercise and throughout recovery. Blood was collected in a capillary tube from a free-flowing digit puncture. Blood lactate values were subsequently evaluated by enzymatic analysis (17). Quality control was maintained by strict adherence to manufacturer standards and control samples. Data were used only after successful calibration of machinery and procedure. Subjects' maximal oxygen consumption were determined during a treadmill protocol with incremental increases in speed and grade as follows: warm-up was 93.5 m-min⁻¹, 10 percent grade, five minutes duration; subsequent stages were two minutes duration at 160.8 m-min⁻¹ and 2 percent grade increases each stage. The subjects ran to exhaustion, with the tests lasting between 10 and 15 minutes after the initial warm-up. Criteria for maximal oxygen consumption were a plateau in VO₂ with increasing grade and a respiratory exchange ratio greater than 1.1 (1). The open circuit technique was used to determine respiratory volumes and fractional components of gases with Bechman MMC. The MMC was calibrated before each test with certified medical gas: grade calibration gas preparations of known concentration. The volume transducer was calibrated by delivery of fixed gas volumes. Blood lactate at maximal oxygen consumption was determined as previously mentioned by the digit puncture technique. Vertical jump was measured with the highest value recorded after three trials from a standing start position, and the sum of three skinfold sites (chest, abdomen and thigh) was also recorded (18).

Statistical Analysis

Descriptive biometric data, performance characteristics and work and intensity outputs were analyzed by a one-way ANOVA and a post-hoc Student Neuman Kuel's test. Results of the experimental protocol and blood lactate were analyzed by a repeated measures ANOVA (BMDP-2V) and a post-hoc Student Neuman Kuel's test. The relationship between external work, intensity and blood lactate concentration were determined from a heterogeneous subject pool (n = 15) by a standard Pearson Product-Moment correlation. Significance for all variables was established at p < 0.05.

Results

Table 1 provides the biometric characteristics of the three groups. The ET group was significantly older
Table 1. Descriptive Biometric Data for the Three Groups

<table>
<thead>
<tr>
<th></th>
<th>UT</th>
<th>WT</th>
<th>ET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>24.2 ± 5.8</td>
<td>20.8 ± 1.6</td>
<td>29.0 ± 8.9*</td>
</tr>
<tr>
<td>HT (cm)</td>
<td>176.5 ± 5.1</td>
<td>183.9 ± 6.9</td>
<td>181.9 ± 5.0</td>
</tr>
<tr>
<td>WT (kg)</td>
<td>82.1 ± 18.0</td>
<td>93.0 ± 10.2*</td>
<td>74.5 ± 4.0</td>
</tr>
<tr>
<td>SF (mm)*</td>
<td>60.5 ± 39.9*</td>
<td>45.4 ± 18.8*</td>
<td>29.9 ± 4.7</td>
</tr>
</tbody>
</table>

Values represent mean ± SD
*Values represent sum of chest, thigh and abdominal skinfold sites
*Significantly different from both of the other two groups (p < 0.05)
HT = Height; WT = Weight; SF = Skinfold

Table 2. Performance Characteristics of the Three Groups

<table>
<thead>
<tr>
<th></th>
<th>UT</th>
<th>WT</th>
<th>ET</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\dot{V}O_2) max (ml·kg(^{-1})·min(^{-1}))</td>
<td>44.8 ± 4.7</td>
<td>46.3 ± 5.6</td>
<td>59.1 ± 1.3*</td>
</tr>
<tr>
<td>La max (mM·l(^{-1}))</td>
<td>10.2 ± 3.0</td>
<td>9.9 ± 0.9</td>
<td>10.4 ± 2.0</td>
</tr>
<tr>
<td>1 RM (kg)</td>
<td>200.4 ± 41.4</td>
<td>285.0 ± 11.2*</td>
<td>216.8 ± 31.4</td>
</tr>
<tr>
<td>VJ (cm)</td>
<td>47.5 ± 6.4</td>
<td>57.1 ± 8.6</td>
<td>49.5 ± 7.3</td>
</tr>
<tr>
<td>1 RM (kg·kgBW(^{-1}))</td>
<td>2.46 ± 0.35</td>
<td>3.10 ± 0.46</td>
<td>2.91 ± 0.44</td>
</tr>
<tr>
<td>TE (min)</td>
<td>2.10 ± 0.21</td>
<td>2.60 ± 0.78</td>
<td>2.34 ± 0.79</td>
</tr>
</tbody>
</table>

Values represent mean ± SD
*Values represent maximal blood lactate at \(\dot{V}O_2\) max.
*Significantly different from other groups (p < 0.05).
VJ = Vertical Jump; TE = Time to Exhaustion; 1 RM = One Repetition Maximum; La max = Blood lactate at \(\dot{V}O_2\) max; UT = Untrained; WT = Weight Trained; ET = Endurance Trained

and the WT group significantly heavier than the other two groups. The ET group was leaner than both of the other groups, as indicated by the significantly smaller skinfold measurements, while the WT group was leaner than the UT group.

Since the groups were divided according to training histories, the ET group outperformed the other two groups on the \(\dot{V}O_2\) max test (Table 2). Maximal blood lactate values were determined at the point of termination of the \(\dot{V}O_2\) max test with all groups producing similar values. The WT group was significantly stronger on the 1 RM test and also showed a trend toward a higher vertical jump, but this value was nonsignificant between groups. When
expressed relative to body weight, however, the groups demonstrated similar leg press strength. Time to exhaustion for each group was similar owing to the similarity between the groups for total repetitions completed (Table 4).

Because of the greater 1 RM performance, which resulted in a greater bar mass for the WT group at each set, the WT group produced more external and relative work at each set except for the last set (Table 3). The greater number of repetitions at 70 percent 1

Table 3. Results of the Experimental Protocol

<table>
<thead>
<tr>
<th>Weight Trained</th>
<th>60% 1 RM</th>
<th>70% 1 RM</th>
<th>80% 1 RM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reps (#)</td>
<td>46.2 ± 9.5</td>
<td>22.8 ± 6.8§</td>
<td>10.8 ± 9.1</td>
</tr>
<tr>
<td>EW (J)</td>
<td>33,208 ± 7,930*</td>
<td>18,672 ± 3,309*</td>
<td>9,844 ± 7,402</td>
</tr>
<tr>
<td>RW (J·kg⁻¹)</td>
<td>359.1 ± 85.3§</td>
<td>204.8 ± 56.3§</td>
<td>111.4 ± 90.2</td>
</tr>
<tr>
<td>ExIn (Watts)</td>
<td>359.1 ± 44.0*</td>
<td>418.8 ± 51.5*</td>
<td>478.7 ± 58.6*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Endurance Trained</th>
<th>60% 1 RM</th>
<th>70% 1 RM</th>
<th>80% 1 RM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reps (#)</td>
<td>43.6 ± 8.6</td>
<td>22.8 ± 4.9§</td>
<td>10.2 ± 4.0</td>
</tr>
<tr>
<td>EW (J)</td>
<td>22,074 ± 4,909</td>
<td>13,377 ± 2,646+</td>
<td>7,053 ± 3,249</td>
</tr>
<tr>
<td>RW (J·kg⁻¹)</td>
<td>294.2 ± 51.1</td>
<td>178.5 ± 27.2$</td>
<td>93.9 ± 42.0</td>
</tr>
<tr>
<td>ExIn (Watts)</td>
<td>252.9 ± 23.0</td>
<td>295.0 ± 26.8</td>
<td>337.1 ± 30.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Untrained</th>
<th>60% 1 RM</th>
<th>70% 1 RM</th>
<th>80% 1 RM</th>
</tr>
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<tbody>
<tr>
<td>Reps (#)</td>
<td>37.0 ± 3.9</td>
<td>14.4 ± 2.2</td>
<td>6.8 ± 3.7</td>
</tr>
<tr>
<td>EW (J)</td>
<td>19,330 ± 4,117</td>
<td>8,801 ± 2,357</td>
<td>4,951 ± 3,260</td>
</tr>
<tr>
<td>RW (J·kg⁻¹)</td>
<td>237.7 ± 34.6</td>
<td>109.0 ± 25.2</td>
<td>59.8 ± 39.0</td>
</tr>
<tr>
<td>ExIn (Watts)</td>
<td>261.4 ± 50.3</td>
<td>304.9 ± 58.6</td>
<td>353.8 ± 72.6</td>
</tr>
</tbody>
</table>

Values represent mean ± SD
*Significantly different from other groups (p < 0.01).
§Significantly different from untrained group (p < 0.05).
*Significantly different from untrained group (p < 0.01).
EW = External Work; RW = Relative Work; ExIn = Exercise Intensity; 1 RM = One Repetition Maximum

Table 4. Work and Intensity Outputs

<table>
<thead>
<tr>
<th></th>
<th>UT</th>
<th>WT</th>
<th>ET</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEW (J)</td>
<td>33,081 ± 8,983</td>
<td>61,725 ± 12,383*</td>
<td>42,504 ± 9,421</td>
</tr>
<tr>
<td>TRW (J·kg⁻¹)</td>
<td>406.6 ± 89.7</td>
<td>675.3 ± 177.7+</td>
<td>566.6 ± 100.0</td>
</tr>
<tr>
<td>TI (Watts)</td>
<td>92.4 ± 22.4</td>
<td>165.8 ± 14.0*</td>
<td>107.2 ± 17.5</td>
</tr>
<tr>
<td>AI (Watts)</td>
<td>69.4 ± 16.7</td>
<td>125.6 ± 8.5*</td>
<td>82.2 ± 13.8</td>
</tr>
<tr>
<td>TR (#)</td>
<td>58.2 ± 7.4</td>
<td>79.8 ± 19.8</td>
<td>76.6 ± 14.2</td>
</tr>
</tbody>
</table>

Values represent mean ± SD
*Significantly different from other group (p < 0.01).
*Significantly different from untrained group (p < 0.05).
TEW = Total External Work; TRW = Total Relative Work; TI = Total Intensity; AI = Average Intensity; TR = Total Repetitions;
UT = Untrained; WT = Weight Trained; ET = Endurance Trained

Journal of Applied Sport Science Research, Volume 4, Number 4, 1990  126
Table 5. Pearson Correlation Coefficients for Predicting Blood Lactate from Workout Intensity and External Work

<table>
<thead>
<tr>
<th></th>
<th>TEW</th>
<th>TRW</th>
<th>TI</th>
<th>AI</th>
</tr>
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<tbody>
<tr>
<td>La</td>
<td>0.62</td>
<td>0.47</td>
<td>0.64</td>
<td>0.66</td>
</tr>
<tr>
<td>p &lt; 0.05</td>
<td>NS</td>
<td>p &lt; 0.01</td>
<td>p &lt; 0.01</td>
<td></td>
</tr>
</tbody>
</table>

*Values represent a heterogeneous pool of all subjects (n = 15).

TEW = Total External Work; TRW = Total Relative Work; TI = Total Intensity; AI = Average Intensity; La = Blood Lactate

Discussion

As pointed out in a recent review (3), the metabolic responses to resistive exercises have received scant attention. This is especially true regarding the blood lactate accumulation following a weight training session. While previous research documented a mild build-up of blood lactate which tended to support the interpretation of a greater reliance on high energy phosphates, recent studies support a much larger proportion of energy generation resulting from glycolysis. A problem contributing to these differing interpretations has been the heterogeneity of the exercise protocols used. More recent studies (11, 12, 20) have employed protocols that alter the exercise:rest ratio, exercise time and total load to produce routines of varying intensities. These have tended to produce higher blood lactate values, a result that substantiates the importance of glycolysis in meeting the energy needs of high intensity resistive exercise.

Although each group exercised to exhaustion, which may tend to introduce a confounding factor in interpreting the results, the differences between groups in total repetitions and time to exhaustion in performing the protocol were nonsignificant. For each of these dependent variables, a nonsignificant test of homogeneity of variance (Barlett-Box Test) was performed to assure that this assumption of ANOVA was maintained. This was necessary because of the striking, though nonsignificant, difference between means that resulted (see Tables 2 and 4). It was expected that each group would finish the protocol with a more equal total repetition production, since the groups were working at the same relative percentage of maximum strength. This was obviously not the case. This result could reflect a difference in volitional drive and pain tolerance by the exercise trained groups. However, that the groups did not differ in fatigue rates is substantiated by the rate of
decline of external work and relative work during the three-set protocol. For each group, the ending external work was approximately 70 percent lower than for the beginning set (Table 3). However, the protocol methodology did produce a greater work output for the WT group, indicating the difficulty in equating volume and intensity variables in studies of this nature.

In support of recent research (11, 19, 20), weightlifting performed with high volumes and loads does activate anaerobic glycolysis. Mean maximal blood lactate values for the WT, UT and ET groups were 11.64, 9.18 and 8.20 mM·L⁻¹, respectively. These values are higher than those reported elsewhere for exhaustive weightlifting using large muscle masses (9, 19), but are neither as high as those determined intramuscularly (20), nor as high as reported values following anaerobic cycle ergometry (6). However, different weight training protocols will produce different blood lactate concentrations (3, 12). Figure 1 demonstrates that the WT group had a greater blood lactate response at each relative resistance. This result is essentially the same as that reported by Stone et al. (19) when trained lifters, because of greater strength, became exhausted at a higher workload than untrained lifters. When compared to novices working at the same absolute submaximal load, the trained lifters exhibited lower blood lactate values (19). There is also a reduced blood lactate in aerobically trained individuals compared to untrained individuals when performing at the same absolute submaximal aerobic power output (5). Therefore, individuals trained either aerobically or anaerobically (when performing submaximally) will accumulate less blood lactate while performing exercises specific to their respective training regimens. Conversely, it is well known that at near maximal power outputs, trained subjects respond with greater blood lactate concentrations than sedentary persons (5). An explanation for the increased blood lactate in this study is the possibility that the WT group had training adaptations increasing their capacity for high intensity work (18). These adaptations may include type IIA fiber conversion to type IIb, increased glycogen stores and/or an increased enzymatic capacity for glycolysis (19). Heavy resistance training may result in biochemical

![Figure 1. The Lactate Response to Weightlifting in Exercise and Recovery (mean ± SD).](https://example.com/lactate 그래프)
adaptations specific to the appropriate energy delivery systems utilized (13). This study, however, permits only speculation on these points which are related to lactate production. The WT group may also have an increased capacity to buffer lactate and the ensuing pH disturbance (16). This would allow for a greater intramuscular lactate accumulation with a subsequently larger blood lactate accumulation. Lactate accumulation in blood is the interplay between production and clearance (2), and is known to be influenced by factors such as lactate efflux from muscle, tissue blood flow and peripheral and central uptake of lactate by several different tissue beds, notably, the heart, liver and skeletal muscle. Evans and Cureton (4) suggest a possible training difference in removing blood lactate. Endurance trained subjects may have an enhanced capacity to remove blood lactate owing to an assumed preponderance of type I motor units and a dense capillary network. In the present investigation, the ET and UT groups had similar blood lactate values throughout the exercise protocol (Figure 1). However, at minutes 13 and 15 of recovery, the ET group demonstrated lower blood lactate. Because WT may have a lower capillary density in comparison to UT subjects (21), the ability to clear blood lactate may be proportionately reduced in the WT group. However, bodybuilders may be a unique resistance-trained subgroup in that they have been shown to have increased capillary densities (21). Figure 1 shows that the assumed potential training differences in blood lactate may be in the correct position relative to each group, with the WT group becoming statistically greater at 80 percent 1 RM and remaining in this position throughout recovery.

Interpreting the metabolic consequences of high intensity resistive exercise between groups differing in body size and training history is complicated by the differences in active muscle mass employed. In the present study, the WT group was significantly heavier than the other groups (Table 1), and thus may have been utilizing greater muscle masses (i.e., hip and knee extensors) in performing the leg press exercise. This may have influenced the blood lactate accumulation due to differences in the ratio of upper body mass to lower body mass, especially since ET subjects were utilized. Therefore, the greater absolute lactate values realized by the WT group in this study may be an artifact of the greater work accomplished. It is probable that each group had a similar rate of lactate accumulation relative to body size, since total relative work was not significantly correlated with blood lactate (Table 5). Future cross-sectional research should attempt rigorous control of body weight between groups and/or should equate the actual muscle mass by weight that is utilized. Because of this confounding variable, an interpretation as to actual differences in absolute blood lactate values is not possible. Therefore, the 25 percent greater blood lactate accumulation by the WT group may not represent a real difference. However, beyond these difficulties, other explanations may prove fruitful at this point.

Another explanation is that weightlifters may have a trained psychological/physiological makeup for heavy anaerobic exercise which would allow them to increase volitional drive, thus more fully exhausting their muscle mass during the workout (14, 15, 18) with a concomitant greater lactate production. Again, this explanation is speculative here since no technique was employed to measure this response.

Another possible explanation concerns the work performed and intensity generated during the exercise protocol. Sale et al. (15) and Sale (14) have indicated that the greater maximum force production resulting from resistive training is an interplay of several neurological factors. Trained subjects are able to more fully activate their prime movers (especially the type IIB fibers), are less inhibited by co-contraction of antagonists for any given exercise, can raise the firing rates of motor units for maximum force output and can also maintain sustained activity in high threshold motor units during maximum contractions. Because of these factors, the use of relative resistances in an attempt to equate differentially trained groups confounds the problem of controlling volume when using exercise to exhaustion as the research protocol. Total external work, total relative work, total intensity and average intensity were, therefore, increased in the WT group (Table 4) because of the neural (14, 15) and/or muscular (21) adaptations. These variables are shown to be correlated with blood lactate (Table 5) in this study.

Hunter (9) employed a different protocol when investigating the blood lactate response to weightlifting, and found that blood lactate increased with increasing percentages of 1 RM performed on separate days. However, this response was seen despite a higher work input at lower percentage of 1 RM. In the current investigation there was a linear increase in blood lactate as the percentage of 1 RM increased from set one to set three with a concomitant reduction of absolute and relative external work by approximately 46 percent for each set (Table 3). The exercise protocol also progressed in intensity from set to set. This pattern was the same in each group. From these results, it appears that the blood lactate response to weightlifting may be more related to exercise intensity as each set progresses in degree of difficulty. The WT group was able to perform more absolute and relative work at 60 percent and 70 percent of 1 RM and for the total workout, while simultaneously generating a greater intensity (Tables 3 and 4). This led to a greater blood lactate response despite the fact that each group was working at the
same relative resistance. However, it remains to be seen whether there are training adaptations in the blood lactate response to a given bout of resistive exercise for biometrically-matched groups.

Practical Application

This research confirms the potential contribution of resistive training to improved performances in anaerobic athletes. The evidence from this investigation, while of a secondary nature, indicates a trend toward biochemical advantages derived from weightlifting aside from the usual improvements in strength. Also, performing protocols similar to the one described may give athletes the ability to increase tolerance for high lactate levels if this or similar protocols are utilized in training.

References