Leg and Hip Endurance Adaptations to Three Weight-training Programs

David McGee\(^1\), T. Christopher Jesse,\(^2\) Michael H. Stone\(^3\) and Daniel Blessing\(^4\)

\(^1\)Animal and Dairy Science, Auburn University, Auburn, Alabama 36849; \(^2\)Wellness Center, Johnson City Medical Center Hospital, Johnson City, Tennessee 37601; \(^3\)Health, Leisure and Exercise Science, Appalachian State University, Boone, North Carolina 28608; \(^4\)Health and Human Performance, Auburn University, Auburn, Alabama 36849.

ABSTRACT

McGee, D., Jesse, C., Stone, M.H. and D. Blessing. Leg and hip endurance adaptations to three weight-training programs. *J. Appl. Sport Sci. Res.* 6(2):92-95. 1992. — The purpose of this study was to compare three weight-training methods to measures of high-intensity exercise endurance. Young male subjects were assigned to three groups using the same exercises three days per week. The initial age, height and body mass of the subjects were (mean ± standard deviation): Group N (n = 8, 20.0 ± 2.0 years, 181.0 ± 5.7 cm, 74.5 ± 11.5 kg); Group P (n = 9, 19.3 ± 1.2 years, 179.5 ± 3.0 cm, 72.4 ± 6.4 kg); Group H (n = 10, 20.6 ± 5.0 years, 184.2 ± 6.4 cm, 80.2 ± 11.2 kg). Parallel squats were performed two days per week and 1/4 squats one day per week. Group N used one set of approximately 12 repetitions to failure. Group P used three sets of 10 for two weeks, three sets of five for three weeks and three sets of three for two weeks. Group H used three sets of 10 for the entire seven weeks. Groups P and H used light and moderate warm-up sets before exercise with the three target sets. Body mass was measured on a medical scale. Cycle endurance time (CT) was measured with the subjects riding (60 rpm) at 30 watts (two minutes), 120 watts (two minutes) and 265 watts to exhaustion. Squatting (top of the thigh parallel) endurance measurements began at 60 kg at a cadence of 1 squat per six seconds. Bar mass was raised by 2.5 kg each minute until exhaustion. Maximum mass lifted (MM), total repetitions (TR) and load (repetitions x mass) (L) were calculated. Measures were made at the beginning (T\(_1\)) and after seven weeks of training (T\(_2\)). No differences were found between groups; however, within- group analysis showed significant (p < 0.05) increases over time for both P and H, but not for N, on all measures. These data suggest that one set to failure does not increase high-intensity exercise endurance as effectively as the use of multiple sets of weight training.

INTRODUCTION

Transfer of training effects to performance is greatly influenced by the training method. Resistance training is used to increase maximum strength, power and high-intensity exercise endurance (2, 11). However, within resistance-training circles, some controversy has existed concerning the use of single versus multiple sets of an exercise. While the effects of single sets to failure versus multiple sets on maximum strength have been studied (5, 13), no objective research has evaluated the effects of these programs on various forms of high-intensity exercise endurance. The purpose of this study was to examine the effects of three weight-training programs using the squat on two measures of endurance.

METHODS

Young male subjects (17-26 years) were assigned to three groups that used the same exercises three days per week (Table 1). Subjects were involved in college weight-training classes and performed various exercises typical for these classes. Parallel squats were performed two days per week and 1/4 squats one day per week. Group N (n = 8, 20.4 ± 2.0 years, 181.0 ± 5.7 cm) used one set of 8-12 repetitions to failure. Group P (n = 9, 19.3 ± 1.2 years, 179.5 ± 3.0 cm) used three sets of 10 repetitions for two weeks, three sets of five repetitions for three weeks and three sets of three repetitions for two weeks. Group H (n = 10, 20.6 ± 5.0, 184.2 ± 6.4 cm) used three sets of 10 repetitions for the entire seven weeks. Groups P and H performed a light and a moderate warm-up set, respectively, before the three target sets were performed. Subjects in group N began training with weights, allowing eight repetitions per set; resistance was increased by five pounds (2.27 kg) when 12 repetitions could be performed. Groups P and H progressed at their own rates; care was taken so that the prescribed number of
repetitions and sets were performed at each workout. In Group N the resistance dictated the number of repetitions; a weight was chosen that allowed eight to 12 repetitions. In Groups H and P the number of sets and repetitions dictated the resistance; a specific set and repetition routine was followed by a weight that fit the routine and allowed maximum intensity. If a subject was fatigued, for example, on the second squat day of the week (Friday), the subject was encouraged to reduce the weight in order to make the appropriate number of repetitions for every set. Thus, groups P and H did not train to failure. Rest periods between sets and exercises for each group were approximately three minutes.

Cycle endurance time (CT) was measured with the subjects riding (60 rpm) at 30 watts (two minutes), 120 watts (two minutes) and 265 watts to exhaustion. Squatting (top of the thigh parallel) endurance measurements began at 60 kg at a cadence of 1 squat per six seconds. Bar mass raised by 2.5 kg each minute until exhaustion. Maximum mass lifted/final resistance attained at exhaustion (MM), total repetitions (TR) and load (repetitions x mass) (L) were calculated. Subjects were familiarized with both methods of testing endurance two to three days before the initial measurements. Measures were made at the beginning ($T_1$) and after seven weeks of training ($T_2$). Body mass was measured on a medical scale. Data were analyzed using repeated measures ANOVA and single degree of freedom contrast statements ($p \leq 0.05$).

### RESULTS

No significant difference was found between groups on any measure. Significant within-group changes were found ($p < 0.05$) from pre- to post-training. Groups H and P showed significant increases for CT, MM, TR and L. Group N did not reach significant levels on any variable (Table 2). Table 3 shows the percent and absolute gains for each variable. Table 4 shows the estimated training volume as repetitions and load (repetitions x mass lifted) over seven weeks.

### DISCUSSION

Two factors reflect the pattern of training responses, suggesting quantitatively different changes among groups in high-intensity exercise endurance. First, the significant increases across time for Groups H and P in all

### Table 2. Body Mass and Performance Changes ($\bar{X} \pm SD$)

<table>
<thead>
<tr>
<th></th>
<th>Body Mass</th>
<th>CT</th>
<th>MM</th>
<th>TR</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>N pre</td>
<td>74.5 ± 11.5</td>
<td>464 ± 43</td>
<td>67 ± 5</td>
<td>24 ± 13</td>
<td>1509 ± 858</td>
</tr>
<tr>
<td>post</td>
<td>75.5 ± 11.5</td>
<td>522 ± 60</td>
<td>71 ± 7</td>
<td>35 ± 14</td>
<td>2272 ± 1003</td>
</tr>
<tr>
<td>P pre</td>
<td>72.4 ± 6.4</td>
<td>470 ± 39</td>
<td>67 ± 5</td>
<td>21 ± 10</td>
<td>1251 ± 713</td>
</tr>
<tr>
<td>post</td>
<td>73.5 ± 6.3</td>
<td>540 ± 86*</td>
<td>72 ± 3*</td>
<td>36 ± 8*</td>
<td>2341 ± 616*</td>
</tr>
<tr>
<td>H pre</td>
<td>80.2 ± 11.2</td>
<td>451 ± 46</td>
<td>67 ± 7</td>
<td>23 ± 15</td>
<td>1488 ± 1068</td>
</tr>
<tr>
<td>post</td>
<td>81.3 ± 11.8</td>
<td>581 ± 129*</td>
<td>74 ± 8*</td>
<td>40 ± 19*</td>
<td>2730 ± 1503*</td>
</tr>
</tbody>
</table>

*significant increase pre-post for groups H and P ($p \leq 0.05$)

CT: Cycle time (sec)

MM: Maximum mass lifted (kg)

TR: Total repetitions

L: Load (kg)
Table 3. Absolute and Percent Change in Variables Across Time

<table>
<thead>
<tr>
<th></th>
<th>CT/%</th>
<th>MM%</th>
<th>TR%</th>
<th>L%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group N</td>
<td>58/12</td>
<td>4/6</td>
<td>11/46</td>
<td>763/51</td>
</tr>
<tr>
<td>Group P</td>
<td>70/15</td>
<td>5/7</td>
<td>15/71</td>
<td>1090/87</td>
</tr>
<tr>
<td>Group H</td>
<td>130/22</td>
<td>7/9</td>
<td>17/74</td>
<td>1242/84</td>
</tr>
</tbody>
</table>

CT: Cycle time (sec)  
MM: Maximum mass lifted (kg)  
TR: Total repetition  
L: Load (kg)

performance variables, and second, the differences in percent change for these variables, especially squat endurance, suggest that the improvement for the multiple-set protocols is superior for gaining high-intensity exercise endurance as measured in this study.

The larger percent gains in parameters associated with gains in squat endurance, as compared to cycle endurance (TR and L versus CT), indicate a high degree of training specificity. However, it is evident that some non-specific transfer of training effect did occur in that Groups H and P did significantly increase CT (Table 2).

Theoretical Considerations

Volume of training is equal to the total work accomplished (7, 11). Generally, high volumes of training, not lower volumes (11), produce greater gains in endurance.

The load (repetitions x mass lifted) is a reasonable estimate of weight training volume; the load is proportional to the total repetitions performed (1, 7, 11). Within this context, several variables have to be considered: repetitions per set, number of sets performed and mass lifted.

It is generally accepted (1, 2, 11) that higher repetitions per set (> six repetitions) are more conducive to producing increases in high-intensity exercise endurance than are lower repetitions. Although Group N used sufficient repetitions per set and trained to failure, these data suggest that this alone was not sufficient to stimulate increases in high-intensity exercise endurance to the same extent as multiple sets. Other factors, such as total repetitions per workout or load (repetitions x mass lifted), may be more important. Table 4 shows the estimated average repetitions and load (repetitions x mass) over seven weeks for each group. The groups using higher total volumes (more repetitions and larger loads) had greater gains in cycling and especially in squatting endurance.

It is interesting to note that each endurance test lasted more than 90 seconds. Exhaustive endurance tests are supported metabolically by both anaerobic and aerobic mechanisms (9, 14). The contribution of aerobic bioenergetic mechanisms to exhaustive cycle exercise becomes primary after approximately 60 to 90 seconds (9, 14) and thereafter increases markedly with time of exercise. Greater anaerobic or aerobic capacity may increase endurance time in these types of tests (14). Increases in aerobic power (max VO₂) should affect increases in aerobic power capacity (ability to maintain aerobically supported power output). Weight training has been shown to increase cycle ergometer and treadmill times during exercise, which is believed to be primarily supported by aerobic mechanism, without marked increases in aerobic power (3, 4, 10). The exact reasons for the increases in endurance are not clear but are related to a number of possibilities, including increases in the rate and capacity to supply energy anaerobically (6, 9, 12), changes in motor-unit recruitment, as well as increases in maximum strength, volitional drive, lactic acid buffering capacity and lactate threshold (3, 4, 9, 12). It is unlikely that weight training of the types used in this study markedly affected aerobic power or expanded aerobic capacity (3, 4, 10); it is more likely that the observed increases in high-intensity exercise endurance related to an increase in anaerobic metabolic or neuromuscular (e.g., increased maximum strength) factors. Thus, it may be argued that the increases

Table 4. Estimated Average Volume Over 7 Weeks

<table>
<thead>
<tr>
<th>Group</th>
<th>Rep</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>150</td>
<td>11061</td>
</tr>
<tr>
<td>P</td>
<td>387</td>
<td>22163</td>
</tr>
<tr>
<td>H</td>
<td>610</td>
<td>35976</td>
</tr>
</tbody>
</table>

Volume = Repetitions  
Load = Repetitions x mass lifted (kg)

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in high-intensity exercise endurance resulted primarily from an increase in anaerobic power capacity (ability to sustain anaerobically supported power outputs), and that multiple sets of weight-training exercise enhance anaerobic power capacity to a greater extent than a single set. An alternate possibility is that these tests are not as aerobic as believed; this certainly may be true of the squat test, which is more intermittent in nature than the cycle test, and may be greatly influenced by maximum strength (11, 12). It may also be possible that training may change the relative contribution from aerobic or anaerobic systems to high-intensity endurance (14), thus (in this study) allowing a greater contribution from anaerobic mechanisms.

**SUMMARY**

The results of this study suggest that multiple sets of weight training can increase the high-intensity exercise endurance of the leg and hip musculature better than single sets. Additionally, the increase in high-intensity exercise endurance may be related to the training load.

Of interest for future studies: Group P used a protocol of decreasing volume and increasing training intensity (estimated by the average mass lifted) over the seven weeks of the study. Some studies and reviews have noted that this type of protocol produces superior strength gains compared to other protocols (7, 8, 11), including one set to exhaustion (13). It should be noted that even though volume and load decreased, the gains in high-intensity endurance within Group P reached significant levels and that the percent gains, especially for total repetitions and load for the squat test, were similar to the highest volume group (H). It is possible that these gains in high-intensity exercise endurance were largely accounted for during the first few weeks of training and carried over to week seven (7, 8, 11), or that the increase in training intensity and the possible superior gains in strength (compared to Groups H and N) resulted in increased endurance.

**PRACTICAL APPLICATIONS**

The use of multiple sets is generally considered to produce superior gains in strength and power compared to single sets, because of greater volume exposure in training. This is especially true when used over relatively long periods of time ranging from several months to years (1, 2, 11). The results of this study also suggest that weight training using multiple sets for the selected free-weight exercises produced better gains in high-intensity exercise endurance when compared to single sets. It is particularly important that these differences in high-intensity endurance were apparent after seven weeks. This is because many off-season programs for athletes last for short periods of time (seven to 10 weeks). Consideration of the present data and previous studies as a whole indicate that athletes who need great maximum strength, power and high-intensity exercise endurance may better increase these parameters using multiple sets of weight-training exercises rather than single sets.

**REFERENCES**