The Effects of Compensatory Acceleration on Upper-Body Strength and Power in Collegiate Football Players

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ABSTRACT

The purpose of this study was to compare the effects of maximum concentric acceleration training versus traditional upper-body training on the development of strength and power of collegiate NCAA Division 1AA football players. Power was tested with a seated medicine ball throw (n = 30) and a force platform plyometric push-up test (n = 24). Upper-body strength was tested by using a bench press with 1 repertition maximum (1RM) (n = 30). All players were on an identical off-season weight-training program. The control group performed exercises with conventional concentric velocity, and the experimental group performed the concentric phase of each repetition as rapidly as possible. Two-way repeated-measures analysis of variance was used to determine training and group differences. Significant training effects for all strength and power measures indicated that both groups increased strength and power. Significant training by group interaction indicates the experimental group increased significantly more than the control group in the bench press (19.85 kg vs. 15.00 kg) and throw (10.69 m vs. 10.22 m). Significance was not reached for any of the training by group interactions for force platform variables (amortization time 20.46 seconds for the experimental group vs. 20.22 seconds for the control group; average power was 1365 W for the experimental group vs. 1108 W for the control group). The results of this study support the use of maximal acceleration of concentric contractions by collegiate football players during upper-body strength and power training.

Key Words: strength training, force/velocity relationship, power


Introduction

The sport of American football places a great demand on an athlete's ability to produce both muscular strength and power. However, confusion exists over how to best improve these 2 components (14, 16).

It has been suggested that strength is best developed using heavy resistance and slow velocities but that low resistance, high-velocity movements are best for developing power (3, 13, 16). Research on training programs using different speeds of contraction have found strength gains are velocity-specific (4–7). Consistent with the concept that high-velocity training may be better at improving power, Roberts (13) found lighter resistance (loads of 30% of 1 repetition maximum [1RM]) lifted with maximum concentric acceleration yielded optimal power outputs.

However, Young and Bilby (17) suggest there may be an increase in power, even if heavy weights are used, if individuals make a conscious effort to maximize accelerate the weight concentrically. Behm and Sale (1) found that the intention to accelerate each repetition as rapidly as possible, regardless of the load, is the key to improvement of power. Supporting this concept, Hunter and Culpepper (8, 9) have shown that training with fixed resistance will increase strength over a wide range of testing velocities as long as the subjects attempt to accelerate during each contraction.

The purpose of this study was to determine what effects maximal concentric acceleration strength training and strength training that includes lower accelerations have on bench press 1RM and shoulder joint horizontal flexion/elbow extension power in NCAA 1AA collegiate football players.

Methods

Subjects

Forty collegiate NCAA Division 1AA football players volunteered to participate in the study (Table 1). Twen-
ty players were randomly assigned to 1 of 2 experimental groups, the control group or the experimental group. Six subjects did not complete the study because of injuries sustained in spring football training, and 4 were unavailable for posttesting. Thirty subjects \((n = 15\) for both experimental and control groups) completed the training and the pre- and posttesting comparing the bench press and seated medicine ball throw, but because of final exam class schedules, only 24 of 30 (12 in each group) completed the plyometric push-up posttest. No pretest differences were observed between groups for body weight, strength, and power. No subjects were injured during weight training. The subjects’ ranges of weight-training experience was 3 to 12 years. Internal Review Board approval was obtained. All subjects were fully informed of all of the risks and stresses associated with the project and signed consent forms before participating.

**Design**

The experimental group members performed all upper-body exercises with maximal acceleration, and the control group members performed all upper-body exercises with acceleration normally used in their training. Contraction times (determined with a stopwatch) were measured during the bench press on 4 subjects and average contraction velocities calculated. Control training velocity while performing the bench press varied from 1.14 m/s on the first repetition to 0.67 m/s on the last repetition when using 50% 1RM, from 0.52 m/s on the first repetition to 0.17 m/s on the last repetition at 75% 1RM, and from 0.37 m/s on the first repetition at 0.13 m/s on the last repetition at 90% 1RM. Experimental training velocity while performing the bench press varied from 1.32 m/s on the first repetition to 0.78 m/s on the last repetition when using 50% 1RM, from 0.64 m/s on the first repetition to 0.21 m/s on the last repetition at 75% 1RM, and from 0.42 m/s on the first repetition at 0.16 m/s on the last repetition at 90% 1RM.

Training was a part of a NCAA Division 1AA football team off-season program that lasted 14 weeks. Pretesting was done during the last week of January after the players returned from winter break. Posttesting was done within 1–2 days after the 14 weeks of training. The 14 weeks were divided into 3 phases. Phases 1 and 3 each consisted of 5 weeks of periodization training as recommended by Stone et al. (15). Phase 2 (during weeks 6–9) consisted of maintenance training during spring football practice. Although training varied slightly between various positions (offensive linemen, offensive backs, defensive linemen, and defensive backs) training was the same for all players in a position group. Equal numbers of players from the 4 position groups were in the control and experimental groups. The program outline is contained in Table 2. The purpose of varying the intensity levels was to prevent overtraining and maintain variety. Weight training was performed with free weights twice a week using a split program for upper- and lower-body exercises. Approximately 50 minutes were devoted to weight resistance exercises, followed by 20 minutes of sprint, agility, and/or anaerobic interval training. Both the control and experimental groups trained identically, except that the experimental group attempted to accelerate all repetitions with the upper-body weight-training exercises whereas the control group made no attempt to maximize acceleration. Throughout the training and testing, proper lifting techniques were highly emphasized. Each repetition was lowered at a deliberate speed, which prevented any bouncing effects that might potentially increase the likelihood of injury.

**Weight Training**

Upper-body exercises performed were the bench press, incline bench press, close grip bench press, behind the

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**Table 1.** Subject characteristics (mean ± standard deviation [SD]).

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (yr)</th>
<th>Height (m)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>19.9 ± 0.8</td>
<td>1.8 ± 0.1</td>
<td>103.5 ± 19.3</td>
</tr>
<tr>
<td>Experimental</td>
<td>20.1 ± 0.9</td>
<td>1.8 ± 0.1</td>
<td>92.1 ± 15.1</td>
</tr>
</tbody>
</table>

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**Table 2.** Outline of the weight program that was followed by the subjects during the weight-training portion of the study.

<table>
<thead>
<tr>
<th>Week No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
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</thead>
<tbody>
<tr>
<td>Full range of motion sets</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Partial sets</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Repetitions</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Percentage repetition maximum, low</td>
<td>65</td>
<td>70</td>
<td>75</td>
<td>80</td>
<td>85</td>
<td>80</td>
<td>85</td>
<td>80</td>
<td>85</td>
<td>90</td>
<td>90</td>
<td>95</td>
<td>90</td>
<td>95</td>
</tr>
<tr>
<td>Percentage repetition maximum, high</td>
<td>50</td>
<td>55</td>
<td>55</td>
<td>60</td>
<td>60</td>
<td>65</td>
<td>65</td>
<td>65</td>
<td>65</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>75</td>
<td>75</td>
</tr>
</tbody>
</table>
The lower-body exercises performed were the parallel squat, variations of the Olympic-style clean, Russian hamstring curl, and Romanian deadlift. There was 1 heavy load day and 1 light load day for both the upper and lower body each week. Each athlete rested 2 minutes between sets. Following the last set of full range of motion repetitions for each upper-body exercise, 1 set of “partial” repetitions was performed. This set was performed with the same load and number of repetitions used for the previous full range of motion set. These partial lifts were done with the assistance of a partner. As the athlete lowered the bar, his partner would give the command “now.” Upon hearing this command, the athlete would stop the eccentric phase and lift the bar to complete arm extension (Figure 2). Both groups performed partial movements, with the experimental group maximally accelerating the bar upward and the control group accelerating the bar at a more deliberate speed. Partial movements were used as a means to eliminate variances in deceleration rates associated with compensatory acceleration.

### Testing

At the beginning of the study and after the completion of the 14 weeks, the players were tested in the 1RM bench press, seated medicine ball throw, and the plyometric push-up. Bench press strength was measured.
with free weights. Subjects warmed up with the weight each normally used as a warm-up in training. Subjects then attempted successive bench presses, gradually increasing the weight until failure occurred. Hips were kept on the bench and the bar was paused at the chest. The highest success was considered as 1RM, which was reached in 3 to 4 trials in all cases.

A 12-pound medicine ball was used to determine seated 2-handed medicine ball distance (11). Subjects were tested in 3 throws after 3 warm-up throws. The trial thrown the farthest distance was used for evaluation. The subjects sat on a 20-inch bench with his back against a wall. Throughout the execution of the throw, the back and scapulae stayed in contact with the wall.

A plyometric push-up was used to test average power, amortization time, and peak force. The test-retest reliability has been previously reported (10) \((r = 0.89\) average power, \(r = 0.92\) amortization time, and \(r = 0.83\) for peak force). The subject placed each hand on a 27-cm-high box with arms extended (Figure 3) and dropped off the box and onto a force plate directly under him (Figure 4). Upon contact with the force plate, the subject stopped descent and accelerated upward as rapidly and forcefully as possible so that he could land on the box and resume the starting position (Figure 5). The subjects performed 3 practice trials the day before testing. Three trials were performed on the test day, with the average of the second and third trials reported. Three measures were evaluated from the force plate data: amortization time \((T3 - T1,\) with \(T1\) being the time recorded that the subject’s hands strike the platform and \(T3\) the time designated that the subject lost contact with the force platform), peak force \((F2)\) on the platform, and average power during amortization time (average force \(\times\) distance [vertical distance to blocks]/time on platform), where the distance traveled equaled the height of box (Figure 1).

All results were analyzed by using a \(2 \times 2\) repeated-measure analysis of variance (multivariate analysis of variance was used). Significance was set at \(p \leq 0.05\).

**Results**

No significant group effects were found for any of the tests; however, significant training effects were found for all tests. The data are presented as means \(\pm 1\) standard deviation (SD). The treatment by group effect indicates that the experimental group increased significantly more than the control group in both the 1RM
Table 3. Results of the seated medicine ball throw and the bench press at 1RM (mean ± SD).*

<table>
<thead>
<tr>
<th>Results</th>
<th>Seated medicine ball throw (m)</th>
<th>Control group (n = 15)</th>
<th>Experimental group (n = 15)</th>
<th>Bench press (kg)</th>
<th>Control group (n = 15)</th>
<th>Experimental group (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td></td>
<td>7.9 ± 0.5</td>
<td>7.3 ± 0.4</td>
<td>130.0 ± 18.2</td>
<td>114.7 ± 17.2</td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td></td>
<td>8.1 ± 0.6</td>
<td>8.0 ± 0.5</td>
<td>135.0 ± 19.0</td>
<td>125.5 ± 15.5</td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td></td>
<td>+0.2</td>
<td>+0.7</td>
<td>+5.0</td>
<td>+9.8</td>
<td></td>
</tr>
<tr>
<td>Percentage change</td>
<td></td>
<td>+2.8</td>
<td>+9.4</td>
<td>+3.8</td>
<td>+8.6</td>
<td></td>
</tr>
</tbody>
</table>

* For both the seated medicine ball throw and the bench press, no significant group effects were found. There was also found to be a significant group by training interaction effect for both. Significant training effects were found for all tests.

bench press and in the seated medicine ball throw for distance (Table 3). Percent increases were over 2 times more for the experimental group for both tests.

For the plyometric push-up test, the significant treatment effect indicates that a significant decrease in amortization time and increase in peak force and average power occurred for both groups. There was no significant treatment by group interaction for any of the force platform variables. However, power for accepting the null hypothesis was low. Decrease in amortization time was over 2 times as great with the experimental group (p = 0.18) and increase in average power output was over 3 times as great with the experimental group (p = 0.12).

**Discussion**

This is the first study to show that in trained collegiate football players, the intent to maximally accelerate concentrically with heavy weights may be better for improving strength and power than slower heavy strength training. The differences between the 2 groups were graphic, with the experimental group sig-
significantly increasing the bench press and throw over twice as much as the control group.

The increased strength and power outputs by the experimental groups found in this study were consistent with increases in strength at a variety of testing velocities previously shown following maximum acceleration knee extension (9) and knee flexion (8) training. Because training was performed using free weights rather than speed-controlled isokinetic apparatuses, velocity of each lift varied with each repetition as the weight was maximally accelerated in both the Hunter and Culpepper studies (8, 9) and this study. Therefore, work was executed over a spectrum of velocities. Velocity also varied dependent upon the intensity of training in this study: higher intensities were moved more slowly. For example, velocity during explosive lifting varied from 1.32 m·s⁻¹ on the first repetition to 0.78 m·s⁻¹ on the last repetition when using 50% 1RM, from 0.64 m·s⁻¹ on the first repetition to 0.21 m·s⁻¹ on the last repetition at 75% 1RM, and from 0.42 m·s⁻¹ on the first repetition at 0.16 m·s⁻¹ on the last repetition at 90% 1RM.

The football players in this study were similar in strength and size to other NCAA Division 1AA players (2), which implies that these results would apply to other Division 1AA programs. Since partial lifts were included in the training program, the results may only be germane to programs that include partial lifts. Newton and Kraemer (12) suggest that with strength training that includes maximal acceleration, deceleration during the latter parts of the range of motion will occur. This may present a problem in achieving optimal increases in strength throughout the range of motion, since reduced muscular force would occur during the deceleration phases of the bar. Hypothetically, this may reduce strength adaptations over this part of the range of motion. Supporting this hypothesis, trends toward reduced strength gains have been previously reported early in the range of motion during training that did not include preloading (8, 9). In order to increase the likelihood that the athletes were stressed adequately late in the range of motion, we included partial movements. Since the bar was accelerated from a negative acceleration (still going down) to maximal positive acceleration (going up) over the problematic range of motion, we feel that adequate exercise stress would have occurred. Obviously, since partials were included in both the experimental and control groups and since strength changes were not evaluated over specific positions in the range of motion, we cannot determine whether the partials were necessary for the greater improvement found with the acceleration group. However, generalizations of results can be made only for strength programs that include both full and partial repetitions.

**Practical Applications**

These results indicate that training with maximal acceleration may be better for developing strength and power. We recommend that with an upper-body strength program similar to that used in this study, training for strength and power should be performed with maximal acceleration. Although the study did not examine lower-body training, other research (8, 9) indicates that similar recommendations could be made for leg exercises.

Future research needs to address the roles of partial movements and different training intensities, as both these factors may have had roles in the strength and power development that were reported.

**References**


6. Hakkinen, K., and P.V. Komul. Changes in isometric force and


