2018

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International Journal of EXERCISE SCIENCE

Original Research

Effects of Very Short-Term Dynamic Constant External Resistance Exercise on Strength and Barbell Velocity in Untrained Individuals

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ABSTRACT

International Journal of Exercise Science 11(1): 867-874, 2018. This study examined the effect of an upper body dynamic constant external resistance (DCER) exercise (barbell bench press [BP]), using the very short-term training (VST) model on strength and barbell velocity. Ten (5 females, 5 males) subjects (mean ± SD age: 21.4 ± 2.8 yrs; height: 1.75 ± 0.12 m; body mass: 83 ± 8.8 kg) completed two pre-test visits (pre-test 1 and pre-test 2) to serve as the within subjects control, three training visits, and one post-test visit. The subject's 1 repetition maximum (1RM) for the BP as well as the mean (BP_{MV}) and peak (BP_{PV}) barbell velocities were determined during pre-test 1, pre-test 2 and post-test visits. The barbell bench press throw (BT) mean (BT_{MV}) and peak (BT_{PV}) velocities were also measured utilizing 35% of the subject's BP 1RM as resistance. The three training visits consisted of 5 sets of 6 repetitions, at 65% of the subject's 1RM. Statistical analyses included one-way repeated measures ANOVAs and paired samples t-tests (alpha level of $p \leq 0.05$). The post-test 1RM, BT_{MV}, and BT_{PV} were all significantly greater than pre-test 1 ($p=0.002$, $p=0.0001$, and $p=0.002$) and pre-test 2 ($p=0.008$, $p=0.034$, and $p=0.015$), with no significant differences seen between pre-test 1 and pre-test 2 for any of the variables. The post-test BP_{MV} and BP_{PV} were significantly greater than pre-test 1 ($p=0.024$ and $p=0.005$), but not pre-test 2 ($p=0.131$ and $p=0.069$). These findings showed the VST model, utilizing an upper body DCER exercise improved strength and barbell velocity in untrained subjects.

KEY WORDS: DCER, VST, bench press, bench throw

INTRODUCTION

Strength and performance adaptations from resistance training exercise programs between 6 to 12 weeks are well documented (12) and result from both neural and skeletal muscle adaptations (1,17). During the initial 1 to 2 weeks of training, significant increases in strength are predominantly attributed to neural adaptations, as increases within this time frame occur too quickly to be fully attributed to hypertrophy of the active muscle (14). These neural adaptations may include increases in motor unit firing rate, increased agonist muscle activation, and/or decreased antagonist muscle coactivation (6,7). The relative contribution of skeletal muscle hypertrophy to strength gains becomes more dominant after 8 to 12 weeks of resistance training (11).

Strength training programs may incorporate isometric, isokinetic, and/or dynamic constant external resistance (DCER) exercises. Dynamic constant external resistance exercise is a commonly used form of resistance training (10) with applications for injury rehabilitation, general fitness and sports performance development. Resistance training programs utilizing DCER exercises have been shown to increase strength in sedentary, active, and highly trained individuals (10) For example, in untrained males, DCER training utilizing the bench press, performed at the 7-repetition maximum (RM) for 1 or 3 sets, resulted in an increase of 9.2 ± 3.9% and 10.1 ± 5.2% respectively, in pre to post training 1RM measures after 6 weeks of training (15). Typically, studies examine training protocols consisting of 18 to 36 training sessions within a 6 to 12-week period (12,15).

In an environment of increasing health care costs and limited medical coverage for injury rehabilitation through physical therapy, the demand for cost-effective alternatives is rising (8,13). Thus, there is a need for a cost effective and time-efficient alternative for those who have limited access to rehabilitation services. The very short-term resistance training (VST) model utilizes 2-3 training sessions to determine the minimal number of sessions necessary to observe the early skeletal muscle and performance adaptations. Previous VST studies have examined the effects of 2-3 days of training on forearm flexor (19,20) and knee extensor performance (2,6,16) using isokinetic forms of exercise. Increases in muscular strength of 2.4% - 22.1% have been reported from 2-3 days of training. (7,16,19,20). Although the effectiveness of VST for increasing strength is well document for isokinetic exercise, no previous studies have examined the applicability of the VST model to DCER exercise for increasing strength and performance measures. The DCER VST model has potential implications for rehabilitation purposes, for examining acute changes in strength and power from nutritional interventions as well as for athlete in-season strength and power maintenance. Therefore, the purpose of this study was to examine the effect of an upper body DCER exercise (barbell bench press [BP]), using the VST model on strength and barbell velocity.

METHODS

Participants

Ten (5 females, 5 males) subjects (mean ± SD age: 21.4 ± 2.8 yrs; height: 1.75 ± 0.12 m; body mass: 83 ± 8.8 kg) with no resistance training experience within the last three months completed this study. The University Institutional Review Board approved this study for Human Subjects. The subjects had no known cardiovascular, pulmonary, metabolic, muscular, and/or coronary heart disease. The subjects were asked to continue with the same weekly exercise and physical activity schedule but to abstain from exercising the day prior to each testing session. All subjects completed a health history questionnaire and sign a written informed consent document before testing.

Protocol

The study involved 7 visits with 48-72 hours between each visit, including an initial familiarization visit, two pre-test visits (pre-test 1 and pre-test 2), three training visits, and one post-test visit. Thus, each subject completed the study, from pre-test 1 to post-test, within 13 to

19 days. For pre-test 1 and pre-test 2, the subject's 1 repetition maximum (1RM) for the BP was measured as well as the mean (BP_{MV}) and the peak (BP_{PV}) barbell velocities from the BP 1RM. The mean (BT_{MV}) and peak (BT_{PV}) velocities were also determined from the barbell bench press throw (BT) test, utilizing 35% of the subject's BP 1RM as resistance. These pre-tests served as the within subjects control phase of the study. Visits four through six included three training visits, which consisted of performing 5 sets of 6 repetitions, at 65% of the subject's 1RM as resistance, with the concentric phase of the BP performed at max barbell velocity. Visit seven, the post-test, followed the same procedures as the two pre-test visits.

The flat bench press 1RM strength testing began with a warm-up set of 8-10 reps, using only the barbell (15-20 kg) as resistance, followed by a 1-minute rest. The second warm-up set was performed at an estimated 50% of the subject's 1RM for 8-10 reps and was followed by another 1-minute rest. The third warm-up set was performed at a resistance 5-10kg higher than the previous warm-up set for of 3-5 reps, followed by another 1-minute rest. The next set was the first test set, using an estimated near maximal (90-95% 1RM) for 2-3 reps followed by a 2-minute rest. An additional 5-10kg was added to the resistance from the previous set and 1 repetition was performed. For each subsequent 1RM attempt, 1-4.5kg of resistance was added after each successful repetition, with 2-minute rest between each attempt. These procedures were continued until the subject failed to successfully perform a repetition through the full range of motion, without bouncing the bar off the chest. The resistance of the last successful repetition was considered the subject's 1RM, with the goal of achieving this within 5 sets. The 1RM bench press velocities for each subject was measured by a GYMAWARE (Kinetic Performance, Australia) linear position transducer, which has previously been shown to provide valid velocity measures for DCER type exercise (4). The GYMAWARE tether was securely fastened with the supplied Velcro strap, 6-8 inches from the end of the bar, on the subject's right side.

Five minutes after the 1RM barbell flat bench press was determined, the subjects completed a bench throw test. The bench throw test was performed on a Smith machine (LifeFitness, Rosemount, IL), with the subject supine on a flat bench. A weight equal to 35% of the subjects' bench press 1RM was used. Thomas et al., (18) suggested 30% of 1RM would elicit peak power outputs for both genders during a bench throw test. In this study, however, the bench throw test was used to examine changes in untrained individuals, who are less strong than the subjects previously used to develop the bench throw test. The lowest resistance that could be applied to the Smith-machine for the bench throw test was 6.8kg. This reflected greater than 30% for some subjects. Therefore, 35% of 1RM was used to allow all of the subjects to perform the test at the same relative % of 1RM. The subjects were instructed to begin the movement with the arms fully extended and then lower the barbell in a rapid but controlled (without pulling or allowing the barbell to bounce off the chest) manner, and then immediately move the barbell as fast as possible from the chest. The bar was released on the throw and caught by the subject as the bar descended by to the start position. The subject completed three throws. The bench throw velocities for each subject was measured by a GYMAWARE linear position transducer (Kinetic Performance, Australia). The GYMAWARE tether was securely fastened with the supplied Velcro strap, 6-8 inches from the end of the bar, on the subject's left side.

Each training session began with two warm-up sets. The first warm-up consisted of 10 repetitions, using only the barbell (males-20kg, females-15kg) as resistance, followed by a one-minute rest. The second warm-up set consisted of 6 repetitions, utilizing 40-45% of the subject's 1RM, again followed by a one-minute rest. However, if 40-45% of the subject's 1RM was lighter than the weight of the bar, the second warm-up set once again used only the bar as resistance. The training session protocol utilized 65% of the subject's 1RM as resistance for 5 sets of 6 repetitions, with one-minute rest between each set. This volume is based on Prilepin's Chart, which has previously been used to determine training volume (9). The subject was instructed to move through the eccentric phase of the lift under control until the bar touched the chest, then to perform the concentric phase of the lift with maximum effort and velocity. Strong verbal encouragement was given for each repetition.

Statistical Analysis

Separate one-way repeated measures ANOVAs and paired samples t-tests were used to determine if there were significant differences among pre-test 1, pre-test 2, and post-test values for 1RM, BP_{MV}, BP_{PV}, BT_{MV}, and BT_{PV}. An alpha level of $P \leq 0.05$ was considered statistically significant for all comparisons. The reliability of each variable from pre-test 1 to pre-test 2 was examined using intraclass correlation coefficients (ICC) model 2,1 (22) and standard error of the measurement (SEM), which was used to calculate the minimum difference (MD). The justification for our N was based on references that indicated 2 to 5 data points per variable is acceptable (3,21). These criteria were met with the use of 10 subjects for examining 5 variables (1RM, BP_{MV}, BP_{PV}, BT_{MV}, and BT_{PV}). All statistical analyses were performed with Statistical Package for the Social Sciences software (v.22.0 IBM SPSS Inc., Chicago, Illinois, USA).

RESULTS

Table 1 shows the mean (±SD) values for pre-test 1, pre-test 2, and post-test for 1RM, BP_{MV}, BP_{PV}, BT_{MV}, and BT_{PV}. There were no significant differences between pre-test 1 and pre-test 2 for any of the variables 1RM, BP_{MV}, BP_{PV}, BT_{MV}, and BT_{PV} (p=0.052, p=0.067, p=0.253, p=0.056, and p=0.175, respectively). In addition, the 1RM, BT_{MV}, and BT_{PV} were highly reliable (ICC = 0.99, 0.89 and 0.92), but BP_{MV} and BP_{PV} demonstrated low reliability (ICC = 0.46 and 0.63, respectively) (Table 1). The post-test 1RM, BT_{MV}, and BT_{PV} were all significantly greater than pre-test 1 (p=0.002, p=0.0001, and p=0.002) and pre-test 2 (p=0.008, p=0.034, and p=0.015). The post-test BP_{MV} and BP_{PV} were significantly greater than pre-test 1 (p=0.024 and p=0.005), but not pre-test 2 (p=0.131 and p=0.069). The individual responses from pre-test 1 to pre-test 2 to post-test are shown in Figure 1A (1RM), Figure 1B (BP_{MV}), Figure 1C (BP_{PV}), Figure 1D (BT_{MV}) and Figure 1E (BT_{PV}).

Table 1. Mean ± SD values for pre-test 1, pre-test 2, and post-test.

	Pre-test 1	Pre-test 2	Post-test	ICC	SEM	MD
1RM (kg)[a,b]	56 ± 25	57 ± 25	59 ± 26	0.99	1.34	3.71
BP_{MV} (m·s^{-1})[a]	0.21 ± 0.10	0.27 ± 0.09	0.34 ± 0.10	0.46	0.07	0.19
BP_{PV} (m·s^{-1})[a]	0.41 ± 0.11	0.45 ± 0.11	0.54 ± 0.13	0.63	0.07	0.19
BT_{MV} (m·s^{-1})[a,b]	0.79 ± 0.11	0.82 ± 0.12	0.84 ± 0.11	0.89	0.04	0.11
BT_{PV} (m·s^{-1})[a,b]	1.41 ± 0.22	1.45 ± 0.24	1.50 ± 0.23	0.92	0.06	0.17

[a]Significant ($p < 0.05$) increase from Pre-test 1 to Post-test. [b]Significant ($p < 0.05$) increase from Pre-test 2 to Post-test. There were no significant differences pre-test 1 to pre-test 2 for any of the variables ($p > 0.05$). Intra-class correlation coefficient (ICC), standard error of the measurement (SEM) and minimum difference (MD) values for Pre-Test 1 and Pre-Test 2 for the subject's barbell bench press 1 repetition maximum (1RM), mean barbell velocity from the subject's 1RM (BP_{MV}), peak barbell velocity from the subject's 1RM (BP_{PV}), mean velocity of the barbell bench press throw test (BT_{MV}), and peak velocity of the barbell bench press throw test (BT_{PV}).

DISCUSSION

To our knowledge, this was the first study to examine the effects of VST on DCER exercise and barbell velocity. The findings from this study indicated an increase in strength and barbell velocity as a result of VST upper body DCER exercise in untrained subjects. Overall, there were significant increases of 3.5% in 1RM, 2.4% in BT_{MV}, and 3.5% in BT_{PV} from pre-test 2 to post-test. Previous research has shown peak torque increases of 2.4% and 4.5% in the forearm flexors of women and men after 3 isokinetic training sessions (19). In addition, VST studies examining lower body leg extensors performance have observed 6% (7) and 22.1% (16) increases in peak torque production after only 2 to 3 training sessions. Thus, the 3.5% increase in 1RM strength in the present study was consistent with the strength increases (2.4% - 22.1%) previously reported (7,16,19,20) for 2 to 3 isokinetic training sessions.

The current study showed non-significant increases of 26% in BP_{MV} and 20% in BP_{PV} from pre-test 2 to post-test. The BP_{MV} and BP_{PV} displayed a high degree of individual variability (Figures 1B and 1C) in the responses across testing sessions, and only 2 of the 10 subjects met or exceeded the MD for BP_{MV} (0.19) and only 3 of the 10 subjects for BP_{PV} (0.19). The low reliability for the BP_{MV} (R= 0.46) and BP_{PV} (R= 0.63) as well as the relatively high SEM (29% and 16% of the mean), and high degree of individual variability may be contributing factors to the observed non-significant differences (p= 0.131 and p=0.069) within these variables. The variability in these measures may be due to the untrained nature of the subjects and lack of familiarity with barbell movements. These findings demonstrated a need for additional familiarization sessions to first establish a reliable 1RM related velocity before beginning the VST sessions.

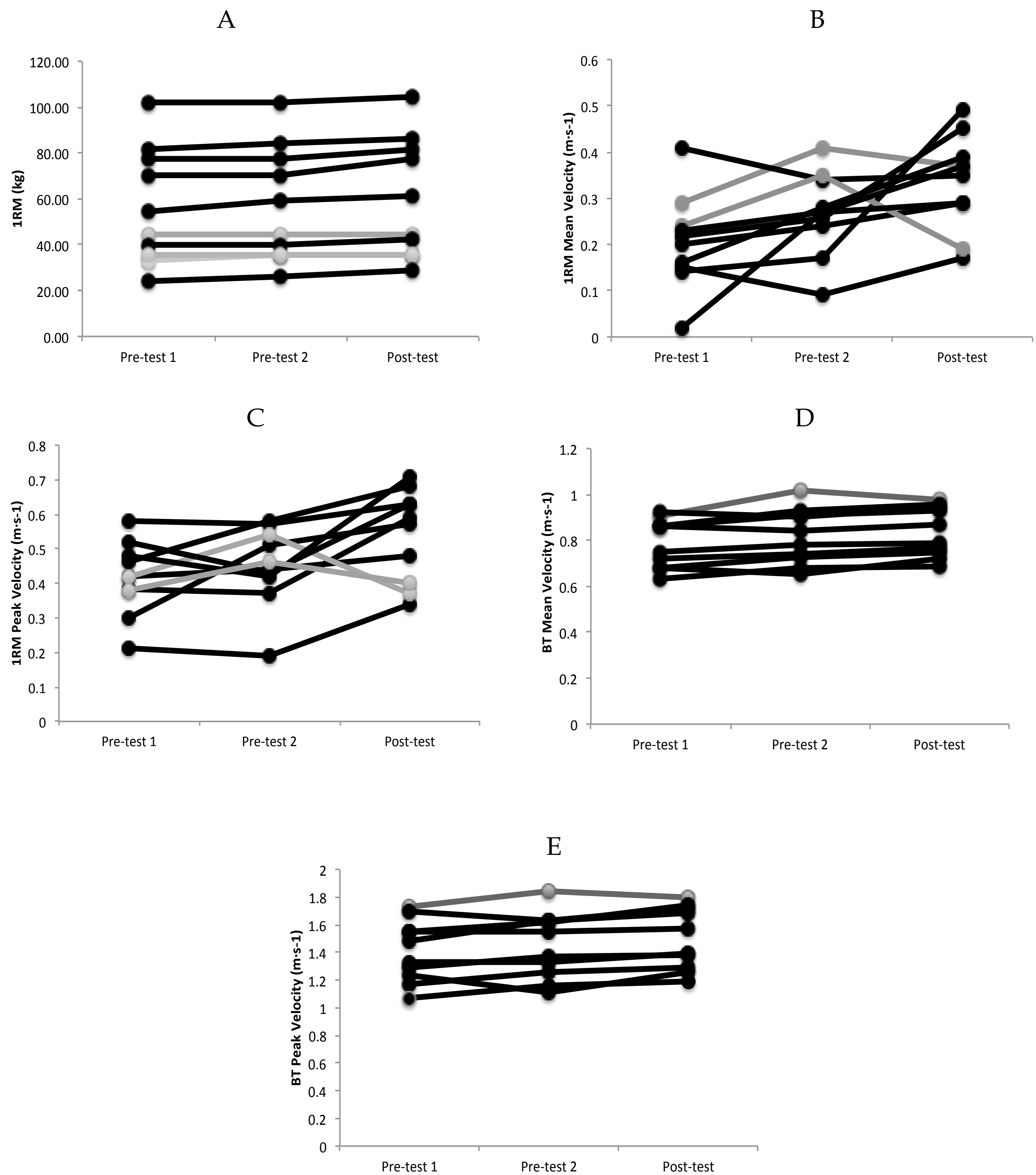

Figure 1. (A) Individual changes in barbell bench press 1 repetition maximum (1RM), from pre-test 1 to pre-test 2 to post-test. (B) Individual changes in 1RM bench press barbell mean velocities (BP_{MV}), from pre-test 1 to pre-test 2 to post-test. (C) Individual changes in 1RM bench press barbell peak velocities (BP_{PV}), from pre-test 1 to pre-test 2 to post-test. (D) Individual changes in barbell bench press throw mean velocities (BT_{MV}), from pre-test 1 to pre-test 2 to post-test. (E) Individual changes in barbell bench press throw peak velocities (BT_{PV}), from pre-test 1 to pre-test 2 to post-test. Black lines indicate an increase and the grey lines indicate a decrease or no change.

A single underlying mechanism explaining the acute strength increases observed from VST type studies has yet to be discovered. It has previously been suggested the strength increases experienced during the first 1 to 2 weeks of resistance training are related to neural adaptations, whereas the strength gains experienced after this initial phase are primarily due to hypertrophy (14). In addition, Cramer et al (7) suggested the early phase training-induced strength changes might be more related to increases in motor unit firing rate of the active muscle, than the recruitment of more motor units (7). Previous researchers have also suggested the strength increases resulting from VST type sessions are, in part, related to increased agonist muscle activation and/or decreased antagonist muscle coactivation (6,7). There are studies, however, that have reported no increased agonist muscle activation after 2 days of isokinetic training. (5). Thus, the potential neural adaptations need to be further examined to identify the underlying mechanism/s behind the early phase training-induced strength observed within VST models.

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