Physiological Responses Using 2 High-Speed Resistance Training Protocols

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ABSTRACT

This study compared physiological responses to 2 high-speed resistance training (RT) protocols in untrained adults. Both RT protocols included 12 repetitions for the same 6 exercises, only differing in continuous (1 × 12) or discontinuous (2 × 6) mode. For discontinuous mode, there was a 15-second rest interval between sets. We hypothesized that the 2 × 6 protocol was less physiologically demanding than the 1 × 12 protocol. Fifteen untrained adults randomly performed the protocols on 2 different days while heart rate (HR), blood lactate (BL), rate of perceived exertion (RPE), and concentric phase mean power (CPMP) were measured. Significantly lower values (mean ± SE) were seen with the discontinuous protocol for exercise HR (119 ± 5 vs. 124 ± 5 bpm), BL (5.7 ± 0.5 vs. 6.7 ± 0.3 mMol/L), and RPE (5.4 ± 0.3 vs. 5.8 ± 0.4) (p < 0.05). CPMP tended to be higher in the discontinuous protocol, especially for the 2 last repetitions. The discontinuous protocol was significantly less physiologically demanding, although similar or higher CPMP values were obtained. These findings may help foster long-term adherence to RT in untrained individuals. However, future studies are needed to compare physiological adaptations induced by these 2 RT protocols.

Key Words: muscle power, heart rate, high-speed strength training, rate of perceived exertion, blood lactate, adherence


Introduction

In recent years, interest in physical activity, both aerobic and resistance exercises (18), has been growing. Various researchers have postulated that resistance training (RT) is the most effective method available for maintaining and increasing lean body mass, increasing muscular strength, and gaining power (5, 14–16, 19, 22). However, approximately half of the individuals who begin a physical activity program drop out within the first weeks (3, 4). Glass and Chvala (6) suggested that for aerobic exercise, adherence could be improved by allowing the participant more freedom to choose the type of activity. No data have been available on different protocols or formats of RT in untrained individuals and their impact on adherence to resistance exercise programs. However, issues of exercise adherence are almost as important as functional gains and health benefits.

Training specificity and results may also favorably affect long-term exercise adherence (6, 7); thus, adherence will be favored if untrained subjects perceive exercise as less demanding, especially at the beginning. There are many RT formats, differing in number of sets or repetitions and in magnitude of loads (13). However, few RT studies have controlled the speed during the concentric phase to optimize training responses (8–10, 17). Jones et al. (8) concluded that heavier training loads and high speed during concentric phase resulted in higher gains of 1 repetition maximum (1RM) in moderately trained subjects. The results of Keeler et al. (9) support the role of high-speed execution during RT. However, studies comparing physiological responses to different set and repetition combinations by untrained individuals for high-speed RT are lacking.

Our purpose was to compare 2 formats of high-speed RT, a discontinuous protocol and a continuous protocol, using the same number of repetitions and identical weights with untrained subjects. We hypothesized that the discontinuous protocol induces less pronounced physiological responses while maintaining similar power outputs.

Methods

Experimental Approach to the Problem

A single group of untrained subjects performed 2 different RT protocols, each including 12 repetitions of 6 different exercises performed always in the same or-
under: (a) rear lat pull-down, (b) seated chest press, (c) knee extension, (d) standing upright row, (e) triceps press-down, and (f) knee flexion. A metronome was set up at 20 strokes per minute, allowing careful control of time for repetitions, i.e., 1 repetition every 3 seconds. Two minutes of rest was allowed between each exercise. The only difference between protocols was presence or absence of a 15-second interval after the sixth repetition. For the continuous RT protocol, the subjects performed 1 set of 12 repetitions (1 × 12), whereas for the discontinuous protocol they performed 2 sets of 6 repetitions (2 × 6) separated by a 15-second interval. Subjects visited the laboratory 3 times, with at least 24 hours between visits. On the first visit, PAR-Q responses (1, 20), and baseline measurements of body weight, height, resting blood pressure, and heart rate (HR) were obtained. To determine maximal power training loads for each of the 6 exercises, power-load curves were obtained. On the next 2 visits, on days 2 and 3, subjects randomly performed the 2 RT protocols, 1 × 12 and 2 × 6, at high speed, i.e., as fast as possible, in the concentric phase of movement using the loads previously selected. During the exercise session, the following physiological variables were measured: (a) blood lactate (BLC, Accusport, Winston-Salem, NC) before and 3 minutes after the last exercise from blood obtained by puncture of the middle finger; (b) HR (Polar NV, Kempele, Finland) at 5-second intervals starting 3 minutes before and ending after the final exercise; (c) rate of perceived exertion (RPE) using the Borg 0–10 scale (2) after each exercise; (d) concentric phase mean velocity (MPCP) measured in watts at a given load were recorded.

Statistical Analyses

Data were summarized as mean ± SD for descriptive statistics and mean ± SEM for inferential statistics. HR, BLC, RPE, and CPMP (in the 12 repetitions) were compared between protocols using paired t-tests. A 2-way analysis of variance (ANOVA) was followed when appropriate by a Bonferroni t-test to compare CPMP among repetitions. A 5% level of probability was considered significant.

Results

Maximum power and corresponding load results, respectively, in the first visit for the 6 exercises were 244 ± 113 W and 31 ± 12 kg for rear lat pull-down, 198 ± 105 W and 28 ± 11 kg for seated chest press, 258 ± 96 W and 33 ± 9 kg for knee extension, 176 ± 88 W and 22 ± 9 kg for standing upright row, 136 ± 69 W and 17 ± 7 kg for standing upright row, and 90 ± 39 W and 13 ± 5 kg for standing upright row.

Although resting HR values were similar (87 ± 14 and 85 ± 15 b·min\(^{-1}\), respectively) for the 1 × 12 and the 2 × 6 protocols, mean HR values at the end of exercise session were minimally higher for the continuous than for the discontinuous protocol (125 ± 5 vs. 119 ± 5 b·min\(^{-1}\); \(p < 0.05\). Resting BLC did not differ between the 2 visits (\(p > 0.05\)). However, BLC and RPE values were slightly but significantly lower 3 minutes after the 2 × 6 protocol (5.7 ± 0.4 and 5.5 ± 0.4 mMol/L) than they were after the 1 × 12 protocol (6.7 ± 0.5 and 5.9 ± 0.4 mMol/L) (\(p < 0.05\)).

MPCP values for the 12 repetitions were almost identical for the 2 protocols except for knee extension, which had 5% higher values in the discontinuous pro-
The merits of high-speed RT have been endorsed recently by a position stand of the American College of Sports Medicine (11). This document also mentions that high-velocity RT may provide specific benefits in different settings and for distinct populations, even elderly individuals. Several studies have favored high-speed training. For example, Tesch (22) reported that for most of the repetitions, the 2 × 6 protocol provided significantly higher scores (p < 0.05) (Figure 2). For almost all of the exercises, there was a small but sometimes significant trend toward lower MCPC values near the end of set, particularly in the last 2 repetitions for the 1 × 12 protocol.

**Discussion**

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HR measurements differed significantly between the 2 protocols. Slightly higher values were found for the 1 × 12 than for the 2 × 6 protocol; however, these differences were quite small and are probably physiologically meaningless. However, significant differences in RPE and BLC favoring lower physiological and perceived demands are more likely to be relevant. These data indicate that a 2 × 6 protocol is physiologically more comfortable, which may enhance long-term adherence in subjects that begin an RT program.

So far, no one has demonstrated that a substantial increase in muscular acidosis induced by an anaerobic glycolysis is needed or even related to the physiological adaptations resulting from RT. Quite often, lactic acid accumulation has been regarded as the most important cause of skeletal muscle fatigue (23). However, results than did slow-contraction isokinetic RT. Based on this assumption, we used high-speed repetitions to work at the maximum level of the power-load curve. No injuries or deleterious effects occurred during or the day following these exercises, suggesting that even for untrained subjects this type of training seems to be safe.

For the rear lat pull-down, knee extension, standing upright row, and knee flexion, MPCP values during the 1 × 12 and the 2 × 6 protocols were different for the last 2 repetitions. Because all repetitions were videotaped, review of the tapes revealed that the quality of execution for the 11th and 12th repetitions performed declined when there was no break after the sixth repetition. This information may be important for evaluating injuries prevention issues during RT.

In the triceps press-down exercise, there were large CPMP variations, which may be due to the fact that there is no formal body support provided during this exercise and thus the muscles of the torso can sometimes be used to assist in completing the movement. This explanation is supported by findings from the seated chest press exercise, the only exercise showing minimal MCPC variations among the repetitions. In this exercise, appropriate torso support maintains appropriate body positioning and isolation of the target muscle groups, reducing the chances for errors in execution.

The CPMP values for the 12 repetitions as a whole did not differ between protocols (p > 0.05). The only exception was the knee extension exercise, for which the 2 × 6 protocol generated higher power than did the 1 × 12 protocol (p < 0.05). For most of the repetitions, there was significantly higher power during the 2 × 6 protocol, suggesting that the 15-second interval may be important in maintaining power (Figure 2). Because this type of effort is primarily dependent on alactic anaerobic metabolism, at least a partial recovery of ATP-CP may have occurred during this rest interval, making it possible to maintain a proportionally higher power in the last repetitions (22).

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recent studies on mammalian muscle, reviewed by Westerblad et al. (23), showed little direct effect of acidosis on muscle function at physiological temperatures. Inorganic phosphate, which increases during fatigue because of breakdown of phosphocreatine, appears to be a major cause of muscle fatigue in vivo (23). MacDougall et al. (12) studied the ratio of substrate energy to production of lactic acid during the biceps press exercise. Their experiment was performed with 8 bodybuilders who completed a typical biceps press training session at 80% of 1RM. Significantly higher BLC values were found after 3 sets than after 1 set of an equal number of repetitions. Brachial biceps biopsies indicated that phosphocreatine and glycogen stores were diminished 62 and 12% and 50 and 24%, respectively, after 1 set and 3 sets. Their conclusion was that muscle fatigue was probably caused by phosphocreatine depletion in the first set and by increase in acidity in subsequent sets.

Analyses of the 4 variables in this study of 6 exercises confirmed our initial hypothesis that a 2 × 6 RT protocol is more cost effective than a 1 × 12 protocol. The discontinuous mode (the 2 × 6 protocol) results produced similar power outputs (and even higher outputs in the last 2 repetitions) while keeping the physiological demands at lower levels. However, it is not clear whether this protocol, although producing similar or slightly higher CPMP values for the same number of repetitions and loads, will be able to induce identical or even larger physiological adaptations to RT.

Practical Applications

These data suggest that splitting a single set of 12 repetitions of 6 commonly used resistance exercises into 2 sets by inserting a 15-second rest interval and using the load in which maximal power was obtained and performing as fast as possible in the concentric phase significantly decreases physiological demands (supported by subjective assessments). The insertion of a rest interval may also allow generation of higher power output while keeping proper execution techniques. These data may encourage the use of this approach, 2 × 6 set or sets, for the increasing number of individuals that are adopting RT exercises as part of a comprehensive exercise program. Preferential use of the 2 × 6 protocol may positively influence long-term adherence, a major goal of health-oriented exercise programs. These 2 RT protocols should be examined further to compare physiological adaptations induced.

References


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