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ORIGINAL ARTICLE

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Resistance training frequency: strength and myosin heavy chain responses to two and three bouts per week

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Abstract Seventeen subjects performed resistance training of the leg extensor and flexor muscle groups two (2/wk) or three (3/wk) times per week. Changes in the relative myosin heavy chain (MHC) isoform contents (I, IIa and IIx) of the vastus lateralis and isometric, isokinetic and squat-lift one-repetition maximum (1RM) strength were compared between conditions after both a common training period (6 weeks) and number of training sessions (18). After 6 weeks and 18 sessions (9 weeks for the 2/wk group), increments in 1RM strength for the 3/wk and 2/wk groups were similar [effect size (ES) differences ≈0.3, 3/wk > 2/wk], whereas the 2/wk group presented greater isokinetic (ES differences = 0.3–1.2) and isometric (ES differences ≈0.7) strength increases than the 3/wk condition. A significant ($P < 0.05$) increase in MHC IIa percentage was evident for the 2/wk group after 18 sessions. Both training groups exhibited a trend towards a reduction in the relative MHC IIx and an increase in MHC IIa contents (ES range = 0.5–1.24). However, correlations between changes in the strength and MHC profiles were weak (r^2: 0.0–0.5). Thus, isometric and isokinetic strength responses to variations in training frequency differed from 1RM strength responses, and changes in strength were not strongly related to alterations in relative MHC content.

Key words 1RM strength · Isokinetic strength · Isometric strength · Inter-session recovery

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Introduction

Strength is required for many functional tasks, from athletic competition to daily living. Resistance training causes increases in strength, however, the relationships between neuromuscular adaptations and the intensity, volume, movement characteristics and frequency of resistance training regimens are complex (Abernethy and Jürimäe 1996; Baker et al. 1994; Weiss 1991).

More frequent training generally produces greater strength gains than less frequent training, as determined by both one repetition maximum (1RM; Gillam 1981; Gregory 1981; Hoffman et al. 1990; Hunter 1985) and isometric strength measurements (Braith et al. 1989; Hakkinen and Kallinen 1994; Pollock et al. 1993). However, Berger (1965) and Graves et al. (1988) reported that manipulating the frequency of training did not significantly effect strength development during rehabilitation. These studies have generated practical information for the design of resistance training regimens. However, because many studies did not control the number of training bouts performed during the various frequency conditions (Braith et al. 1989; Gillam 1981; Graves et al. 1988; Gregory 1981; Hoffman et al. 1990; Pollock et al. 1993) or standardise the characteristics of individual training bouts (Hakkinen and Kallinen 1994; Hoffman et al. 1990), it was not possible to isolate the effects of training frequency.

It is important to consider measurement sensitivity when resistance training regimens are evaluated (Abernethy et al. 1995). For example, greater strength increases occur for movement patterns and contraction modalities performed during training than for novel resistance tasks (Abernethy and Jürimäe 1996; Pearson and Costill 1988; Rasch and Morehouse 1957; Rutherford and Jones 1986; Sale et al. 1992). A possible relationship between the sensitivity of strength measurements and resistance training frequency was examined for both 1RM and isometric strength responses (Logan PA, Abernethy PJ, Carroll T et al. manuscript

in preparation). Greater increases in 1RM strength occurred when training bouts involving dynamic exercises for the lower body musculature were performed every 48 h compared with every 72 h. In contrast, greater isometric strength increases occurred in the condition involving recovery periods of 72 h. These data provide evidence that some mechanisms of isometric and 1RM strength changes are distinct (Abernethy and Jürimäe 1996; Baker et al. 1994).

The purpose of this study was to compare the effects of high-intensity resistance training regimens involving two and three training bouts per week. The changes in strength under 1RM squat lift, isometric, and isokinetic conditions were compared, as were alterations in the relative content of myosin heavy chain (MHC) isoforms (I, IIa, IIx). In order to isolate the influence of training frequency on the responses to training, measurements for each group were taken after both an equivalent time (6 weeks) and number of training sessions (18 bouts).

Methods

Subjects

Eight female and 9 male university students with less than 6 months resistance training experience participated in this study. None of the subjects had performed any resistance exercise in the 6 months prior to the experiment. The subjects were randomly assigned to groups which trained two [2/wk – 2 males, 3 females; mean (SD) height 1.78 (0.11) m; mass 71.1 (18.7) kg; age 19.4 (0.9) years] or three [3/wk – 3 males, 3 females; mean (SD) height 1.75 (0.11) m; mass 69.5 (11.6) kg; age 17.7 (0.5) years] times per week, or to a control condition (4 males, 2 females; mean (SD) height 1.76 (0.04) m; mass 67.4 (3.0) kg; age 18.8 (1.7) years] in which no training was performed. Training sessions were separated by at least 3 days for the 2/wk group (e.g. Mondays and Thursdays), and by at least 2 days for the 3/wk group (e.g. Mondays, Wednesdays and Fridays). Subjects did not perform any other resistance training. All procedures were approved by the Medical Ethics Research Committee of The University of Queensland.

Procedures

The dependent variables were: 1RM for the half squat, unilateral isokinetic and isometric leg extension peak torque of the right leg at 0.79 rad (45°) from full knee extension, and the MHC isoform composition of muscle samples taken from the right vastus lateralis. The order of 1RM strength testing and isokinetic and isometric strength testing was randomised but held constant across time for each subject. The 2/wk group trained for 9 weeks (18 sessions) and the 3/wk group for 6 weeks (18 sessions). All variables were measured before and after the 18 training sessions in both groups. Measurements were also taken after 12 training sessions (6 weeks) in the 2/wk condition to compare conditions after a similar training volume. Each dependent variable, except for MHC characteristics, was measured for control subjects on two occasions separated by 6 weeks. Small changes in MHC isoform percentages ($<4\%$) have been reported to occur in control subjects (Adams et al. 1993; Allemeier et al. 1994; Fry et al. 1993; Jürimäe et al. 1996). Subjects were instructed not to participate in any strenuous or unaccustomed exercise for 72 h prior to each testing occasion.

1RM squat strength

The 1RM for the back, half squat exercise was measured using a Plyopower system (Lismore, Australia) according to Chandler and Stone (1991). The barbell could only be displaced in a vertical plane and featured adjustable stops which delimited the range of motion to a knee angle of $\approx$1.57 rad. The subjects' feet were positioned slightly in front of their centre of gravity and approximately shoulder width apart. The feet position and the positions of the adjustable stops were determined during a familiarisation session and were then duplicated for all subsequent measurements for each subject. The subjects performed two warm-up sets at self-selected, submaximal loads followed by a series of single repetitions with near maximal loads. Loads were sequentially increased until the subjects were unable to lower the barbell in a controlled manner to 1.57 rad, or to lift the weight to its starting position. When this occurred, the load was decreased by increments of 1.25 kg until a lift could be performed correctly or until the next load to be attempted was equal to that achieved in the last successful lift. The heaviest weight to be lifted successfully was recorded as each subject's 1RM and was usually determined within four to six attempts. A recovery period of 3 min was allowed between attempts (Sewall and Lander 1991).

Isokinetic and isometric strength

Measurements of the isokinetic knee extension strength of the right leg were taken with a Cybex 6000 Testing and Rehabilitation System (Lumex, New York, USA) at angular velocities of 1.05, 3.14, 5.24 and 8.73 rad $\cdot$ s^{-1}. Peak torque at 0.79 rad from full knee extension was obtained for each velocity. Range of motion limits were set and a gravity correction procedure was performed prior to all testing. Subjects completed the experimental protocol in the following order: 1.14, 8.73, 1.05, 5.24 rad $\cdot$ s^{-1}, and 0.79 rad isometric. Three submaximal familiarisation repetitions were performed at each angular velocity, immediately followed by five maximal contractions at all speeds except for 1.05 rad $\cdot$ s^{-1}, at which three maximal contractions were performed. Subjects were instructed to extend and flex their leg "as hard and as fast as possible" for each isokinetic trial (Bemben et al. 1990). The maximal voluntary isometric strength of the knee extensors was measured at 0.79 rad from full knee extension. Subjects were instructed to extend their leg slowly until the resistance of the dynamometer was felt. At this point, they were instructed to extend their leg as hard and as fast as possible for 5 s (Bemben et al. 1990). Subjects were provided with immediate visual feedback and verbal encouragement. Sixty seconds were allowed between all trials. Torque curves for all trials were examined to ensure that the peak torque was not contaminated by impact.

MHC analyses

Skeletal muscle tissue samples were taken from the mid-portion of the right vastus lateralis muscle using the true-cut needle biopsy technique of Bergström (1965), and immediately frozen in liquid nitrogen. Following storage at −70°C, the wet weight of each muscle sample was determined and myofibrits were extracted according to Klitgaard et al. (1990). The extractions were diluted 1:1 in glycerol storage buffer (50% glycerol, 100 mM Na_4 P_2O, 5 mM Ethylenediaminetetraacetic acid) stored at −20°C. The protein content of the resultant solutions was determined spectrophotometrically (Biorad Protein Assay, California, USA) and 10-µl aliquots of the buffered solutions, containing 200–250 ng of protein, were analysed via sodium dodecyl sulphate poly-acrylamide gel electrophoresis (SDS-PAGE) according to the procedures described by Jürimäe et al. (1996, 1997). The resultant gels were stained with silver (Biorad Silver Stain kit, California, USA) and the MHC content was quantified using an Arcus II (Agfa Gevaert) scanner interfaced with a computer equipped with NIH Image version 1.58 software (National Institutes of Health, USA). MHC