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The effect of strength training and reduced training on rotator cuff musculature

M.J. McCarrick *, J.G. Kemp

School of Human Movement, Australian Catholic University, Melbourne, Victoria 3065, Australia

Abstract

Objective. Elucidate the training frequency required to maintain strength gains acquired via short-term resistance training on the rotator cuff.

Design. Twenty-one participants performed 12 wk resistance training followed by 12 wk reduced training. Following the training phase (three rotator-cuff-specific exercises; three sessions/wk), participants were randomly assigned to one of three reduced training groups (2, 1 or 0 session(s)/wk).

Methods. Isokinetic testing was done at 0, 6, 12, 18 and 24 wk to obtain mean and peak torque (N m). Testing involved concentric and eccentric actions of internal and external rotation for both shoulders at 60 and 120°/s.

Results. Training produced increases in mean and peak torque for all tests but the four of concentric external rotation. A control group performed no training, showing no changes in strength at 0, 6 and 12 wk. Reduced training (2 or 1 session(s)/wk) produced no decreases in peak or mean torque. Detraining (0 session/wk) produced mean torque decreases in four tests, with eccentric strength showing greater losses.

Conclusions. A training frequency of 1 session/wk maintains rotator cuff strength gains in previously untrained subjects. Further, eccentric strength may be more susceptible to detraining.

Relevance

These findings have direct relevance to functional rehabilitation practices for the rotator cuff. They may aid in resistance training programming for athletes during the off-season or returning from injury, particularly those in overhand sports.

Keywords: Isokinetic; Detraining; Reduced training; Shoulder; Muscle strength

1. Introduction

There is a paucity of data examining the impact that a respite from training may have on shoulder musculature. Most detraining studies have examined leg musculature [1–3], demonstrating a gradual reversal of the effects gained through strength training. However, detraining may affect upper extremity musculature differently due to: (i) fibre type composition variations in different muscles [4,5]; (ii) larger type I cross-sectional area compared to type II fibres in leg muscles [6]; (iii) variations in respective recruitment patterns; and (iv) leg muscles acting as a postural muscles and their use in locomotion. Studies report the maintenance of strength gains for up to 12 wk with reduced training frequencies for the leg extensors [1] and lower back [7]. To guide rehabilitation and/or athletic programs, it is necessary to elucidate what training stimulus is required to maintain training effects in specific muscles. This study investigated the effects of a program of resistance training, followed by a period of detraining and two levels of reduced training, on the strength of the rotator cuff (RC).

2. Methods

Fourteen females and seven males participated in the 24 wk training study. A control group comprised six females and two males. The subjects had no history of shoulder injury, had not participated in resistance training in the previous year and had no history of long-term resistance training.

Mean and peak strength testing utilised the KIN-COM® isokinetic dynamometer (Chattecx, Chattanooga, TN, USA). The KIN-COM® set-up for shoulder

* Corresponding author.

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internal/external rotation was followed. Gravity correction was employed. Testing was performed in an upright seated position. The arm was placed at 30° of forward flexion (i.e., scapular plane) [8,9]. A goniometer was used to measure abduction and forward flexion angles [9]. The test positions were consistent within subjects for each test session.

Each participant undertook a familiarisation session. Test sessions consisted of 3 min warm-up of submaximal rowing (Concept II ergometer) followed by 10 submaximal concentric and eccentric actions of internal rotation (IR) and external rotation (ER) at 120°/s. Mean and peak torque for isokinetic shoulder IR and ER were tested at 60°/s and 120°/s, in that order to enhance reproducibility [10], for concentric and eccentric actions. When testing for each speed, body side and contraction type (each separated by 3 min), IR preceded ER (separated by 5 s). Three consistent force curves were recorded for each motion with concentric preceding eccentric testing. Test side order was randomised between subjects but was held consistent within subject. Torque was measured through 85° of motion, from 90° of ER to 5° of IR.

Twelve weeks of free weight resistance training was followed by 12 wk of reduced training. Three exercises, identified as challenging the rotator cuff muscles [11], included: horizontal abduction external rotation (HAER), scaption internal rotation (SIR) and external rotation (EXR) [11]. Strength training comprised 3 sessions per wk (s/wk) and three sets of 8–12 repetition maxima (RM) per exercise, with each shoulder trained individually. Increases in training weight occurred when participants completed three sets of 12 repetitions. Isokinetic testing was conducted at 0, 6, and 12 wk. Participants were then randomly assigned to one of three reduced training groups. The three groups were: 2 s/wk (Female $n = 5$, Male $n = 2$), 1 s/wk (F $n = 5$, M $n = 2$) and 0 s/wk (F $n = 4$, M $n = 3$). Isokinetic testing was done at 18 and 24 wk. The control group did not perform any training and were tested at 0, 6 and 12 wk.

3. Data analysis

Sixteen isokinetic tests were examined (Table 1). One-way ANOVA with repeated measures on the dependent variables (mean and peak torque) over time (0, 6, 12 wk) was conducted for each isokinetic test for the training and control groups. Two-way factorial ANOVA with repeated measures on the dependent variables over time (12, 18, 24 wk) was conducted for the three reduced training groups. A Bonferroni adjustment was performed, converting $P \leqslant 0.025$. Scheffé post-hoc analysis was used when obtaining a main effect. Training weights lifted were analysed by one-way ANOVA with repeated measures on the dependent variable (training weight) over time. Physical characteristics and initial strength values were compared between the training and control groups using independent t-tests ($P \leqslant 0.05$).

Table 1
Mean torque values (N m) for the training phase. Abbreviations: D – dominant shoulder; ND – non-dominant shoulder; 60 – 60°/s; 120 – 120°/s; con – concentric; ecc – eccentric; IR – internal rotation; ER – external rotation [a]

Group	Training group ($n = 21$)			Control group ($n = 8$)	
Test	0 wk	6 wk	12 wk	0 wk	12 wk
D60conER	19.4 ± 2.0	20.1 ± 1.7	21.3 ± 2.3	17.3 ± 2.5	16.4 ± 2.2
D60conIR[bc]	25.1 ± 3.0	29.3 ± 2.9	31.7 ± 3.2	22.2 ± 3.5	18.0 ± 2.6
D60eccER [bc]	28.9 ± 3.3	34.9 ± 3.5	35.6 ± 3.8	25.8 ± 4.2	28.7 ± 5.1
D60eccIR[c]	22.4 ± 1.8	24.2 ± 1.7	26.0 ± 2.1	21.2 ± 3.1	21.3 ± 3.6
D120conER	15.2 ± 1.5	16.4 ± 1.3	17.2 ± 1.6	14.4 ± 1.7	14.3 ± 1.5
D120conIR[bc]	24.7 ± 2.9	28.4 ± 2.9	29.4 ± 3.0	21.2 ± 3.0	19.3 ± 3.2
D120eccER[c]	30.1 ± 3.3	33.9 ± 3.2	35.0 ± 3.6	25.0 ± 3.7	27.8 ± 5.8
D120eccIR[cd]	27.8 ± 1.9	28.8 ± 1.6	31.3 ± 2.0	26.8 ± 3.4	27.1 ± 3.9
ND60conER	14.1 ± 1.3	14.7 ± 1.3	15.7 ± 1.7	13.5 ± 2.0	12.4 ± 1.7
ND60conIR[bc]	29.8 ± 2.8	34.7 ± 2.8	36.2 ± 3.1	27.9 ± 4.2	29.3 ± 5.3
ND60eccER[bc]	27.8 ± 2.6	33.6 ± 2.9	34.1 ± 3.2	27.5 ± 4.8	30.1 ± 5.4
ND60eccIR[cd]	18.0 ± 1.7	18.8 ± 1.7	21.3 ± 2.0	17.0 ± 2.9	15.9 ± 2.1
ND120conER	12.5 ± 1.2	12.9 ± 1.1	13.6 ± 1.4	11.1 ± 1.9	11.4 ± 1.8
ND120conIR[bc]	23.4 ± 2.4	28.3 ± 2.4	30.7 ± 2.8	21.6 ± 3.9	24.1 ± 4.4
ND120eccER[bc]	33.8 ± 2.3	38.5 ± 2.5	38.6 ± 2.7	32.8 ± 4.7	36.3 ± 4.6
ND120eccIR[cd]	18.4 ± 1.7	18.8 ± 1.6	21.0 ± 1.9	17.1 ± 2.4	15.1 ± 2.0

[a] Values are means ± standard error.
[b] Significant difference from 0 to 6 wk within training group.
[c] Significant difference from 0 to 12 wk within training group.
[d] Significant difference from 6 to 12 wk within training group.

4. Results

4.1. Participants

Training group mean age was 20.15 ± 0.42 y. Control group mean age was 20.64 ± 0.45 y. Physical characteristics (age, height, weight) and initial mean and peak torque values did not differ between groups. The reduced training groups showed no differences in physical characteristics.

4.2. Responses to strength training

Significant mean torque gains were found in 12 of the 16 tests from 0 to 12 wk (Table 1). Of the 12 tests, seven showed significant responses from 0 to 6 wk, and three tests showed gains from 6 to 12 wk (Table 1). The four tests not showing training responses involved concentric ER (D60conER, D120conER, ND60conER, ND120conER). The same 12 strength tests showed peak torque gains (not shown), with the four concentric ER tests showing no improvement. The same seven tests showed increases in peak torque from 0 to 6 wk. Four tests (D120eccIR, ND60eccIR, ND120eccIR, D60eccIR) showed peak torque gains in the 6–12 wk. The mean training weights lifted (not shown) for the training group increased from 0 to 12 wk. No significant differences existed between the training and control groups at 0 wk for mean (Table 1) or peak torque values. No differences in torque values existed within the control group at 0, 6 and 12 wk.

4.3. Responses to reduced training

The 0 s/wk group showed declines in mean strength from 12 to 24 wk for D120eccIR, ND60eccIR, ND120eccIR and D60conIR (Table 2). Overall, both 1 s/wk and 2 s/wk groups exhibited no strength losses for the 16 strength measures (not shown). However, for ND60eccIR in 2 s/wk group, mean torque decreased from 18 to 24 wk, but the mean torque from 12 to 24 wk was not significantly lower. For peak torque (not shown), no significant declines were demonstrated in any of the three groups.

Table 2
Mean torque values (N m) for the detraining (0 s/wk) group. Abbreviations: D – dominant shoulder; ND – non-dominant shoulder; 60 – 60°/s; 120 – 120°/s; con – concentric; ecc – eccentric; IR – internal rotation; ER – external rotation[a]

Test	12 wk	18 wk	24 wk
D60conER	21.9 ± 3.6	22.8 ± 4.4	18.6 ± 3.0
D60conIR[b]	37.5 ± 6.2	33.2 ± 6.7	31.9 ± 4.8
D60eccER	42.1 ± 6.7	38.9 ± 7.6	33.6 ± 6.8
D60eccIR	26.7 ± 3.0	26.1 ± 3.5	25.5 ± 2.8
D120conER	17.4 ± 2.1	17.8 ± 2.2	15.6 ± 2.7
D120conIR	33.0 ± 5.7	32.2 ± 6.9	30.2 ± 5.0
D120eccER	41.5 ± 6.4	40.3 ± 7.0	34.1 ± 6.8
D120eccIR[b]	30.1 ± 3.6	29.9 ± 4.1	26.7 ± 2.9
ND60conER	17.8 ± 2.6	19.1 ± 3.5	15.5 ± 3.4
ND60conIR	35.4 ± 6.0	35.2 ± 6.0	32.9 ± 5.3
ND60eccER	36.2 ± 6.1	35.4 ± 6.1	29.7 ± 4.8
ND60eccIR[b]	24.0 ± 3.2	23.5 ± 3.7	21.8 ± 3.3
ND120conER	15.4 ± 2.6	16.1 ± 3.0	13.8 ± 3.0
ND120conIR	31.5 ± 4.9	30.5 ± 5.2	28.0 ± 3.9
ND120eccER	39.2 ± 4.7	37.8 ± 5.7	32.4 ± 5.1
ND120eccIR[b]	24.2 ± 3.4	23.7 ± 4.1	21.3 ± 3.2

[a] Values are means ± standard error.
[b] Significant difference from 12 to 24 wk for 0 s/wk.

5. Discussion

No changes occurred in mean or peak torque for the control group (Table 1), and no differences in physical characteristics or initial strength values existed between the control and training groups. Thus, the training group increases in 12 tests from 0 to 12 wk (Table 1) must be the result of the training program. The pooling of male and female data may be a limitation; however, several studies report no differences between genders in training-induced strength gains [1,7,12]. Mean torque gains occurred in seven tests from 0 to 6 wk, but only in three from 6 to 12 wk. Neural adaptations during early strength gains [2,13] followed by a relative plateau in strength enhancements have been previously reported [14].

With the four tests of concentric ER failing to display any significant strength gains, the appropriateness of the free weight exercises must be questioned. HAER and EXR are significant stressors of infraspinatus and teres minor [11]. Despite no increases in concentric ER strength, the external rotators did display increased eccentric strength. This supports the effectiveness of these exercises since concentric strength is the limiting factor in resistance work [15]. We suggest that the scapular plane may not be suitable for concentric ER testing (despite this plane being identified as a more favourable position to test shoulder rotators [8,9]), as the line of motion of the dynamometer lever arm may not move with the line of pull of the external rotators. All IR tests showed strength gains, supporting SIR (a prominent stressor of supraspinatus and subscapularis [11]) as an effective exercise.

With 0 s/wk, three of the four tests showing declines in mean torque involved eccentric actions (Table 2). Four other eccentric tests (D60eccER, D120eccER, ND60eccER, ND120eccER) displayed tendencies toward mean torque decreases (Table 2). The small sample sizes in each reduced training group may have lowered the chance of reaching significance in such tests. In power athletes, only eccentric isokinetic force decreased with short-term detraining of 14 days [15]. Preferential recruitment of type II muscle fibres during eccentric actions has previously been identified [16]. The reduced eccentric force may be linked to a reduction in the eccentric stimulus during detraining. Interestingly, only eccentric tests showed strength gains from 6 to 12 wk, then displayed significant detraining over 12–24 wk with 0 s/wk. The strength gains may be due to type II fibre hypertrophy, with the subsequent eccentric detraining resulting from atrophy of these fibres. We found significant detraining in only one concentric motion (D60conIR). Concentric strength has been previously reported to be more resistant to detraining than eccentric strength [16].

The suggestion that eccentric strength is more susceptible to detraining may have major ramifications for the overhand athlete returning to activity following injury or the off-season. The eccentric action dynamically stabilises the shoulder joint by decelerating shoulder IR and ER [17,18]. The arm may have the capability of being accelerated and rotated as normal; however, the potential loss of eccentric strength may impact on the decelerating force. This may reduce dynamic joint stability and increase the joint's susceptibility to injury.

Our study reports no declines in strength over 12 wk of reduced training (2 s/wk; 1 s/wk). Thus, as low as 1 s/wk maintains RC strength gains when other training variables (i.e., intensity, mode) are held constant. Isometric leg extensor and lumbar extension [7] strength has been maintained for 12 wk on previously untrained subjects with 1 s/wk when training intensity is maintained. Training intensity may play an important role in the maintenance of muscular strength [1,7]. It has been suggested that muscle actions need to be performed at high relative force levels to maintain neural drive [2,19]. In our study, the reduced training stimulus was sufficient to maintain eccentric strength. However, previously sedentary individuals maintain training effects for longer periods than athletes [1,19]; thus, maintenance requirements may differ for trained individuals.

6. Conclusions

1. Twelve weeks of resistance training including SIR, HAER and EXR for 3 s/wk is sufficient to increase mean and peak torque for shoulder IR and ER.
2. It appears that 1 s/wk may be sufficient to maintain such improvements for previously untrained participants if training intensity remains.
3. Eccentric strength may be more susceptible to detraining than concentric strength. This should be considered when athletes in shoulder-dominant sports return to activity following a period of quiescence.

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