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The Effects of Strength Training and Detraining on Children

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ABSTRACT

The effects of an 8-week strength training program followed by an 8-week detraining period were evaluated in 11 boys and 4 girls, ages 7 to 12 years. Three boys and 6 girls matched for age and level of maturity served as controls. Progressive strength training was performed twice a week on child-size equipment. Subjects were tested on the following measures: 6 repetition maximum (RM) leg extension, 6-RM chest press, vertical jump, and flexibility. Strength training significantly ($p < 0.05$; ANOVA) increased 6-RM strength on the leg extension (53.5%) and chest press (41.1%), whereas control group gains averaged 7.9%. Strength training did not significantly affect other variables. Detraining resulted in a significant loss of upper (-19.3%) and lower body (-28.1%) strength in the experimental group. The results suggest that participation in a short-term strength training program will increase the strength of children; however, strength gains regress toward untrained control values during the detraining period.

Key Words: weight training, exercise, adaptation, pre-adolescence

Introduction

The benefits of strength training for adult populations are well known (12, 32), and the safety and efficacy of strength training for children continue to be documented (10, 16, 18, 22). Despite the old notion that pre-pubescent children could not increase their strength due to insufficient levels of circulating androgens (1), recent studies have reported significant improvements in strength (11, 15, 19, 24, 25, 29), maximal oxygen uptake (29), body composition (11, 25), blood lipid profiles (30), and motor performance skills (29, 33) following several weeks of strength training.

A variety of strength training programs and modalities have proven to be safe and effective for chil-

dren as long as appropriate training guidelines are followed and there is competent supervision (10). Moreover, youth strength training programs have become important components of injury prevention strategies (3) and public health objectives (8).

However, few studies have explored the effects of detraining on acquired strength gains in adults, and relative information on children is limited. One report (24) and two abstracts (6, 15) have noted decreases in children's strength following several weeks of detraining, yet the precise nature of the detraining response and the physiological adaptations that occur during this period remain undefined. Methodological and informational limitations such as the lack of a control group comparison during the detraining period (24) and the absence of data on strength gains achieved during the training period (6) limit conclusions. Clearly, more information on the effects of detraining on preadolescents is needed.

Detraining may be defined as the temporary or permanent reduction or withdrawal of a training stimulus which may result in the loss of anatomical and physiological adaptations as well as a decrease in athletic performance. A better understanding of the detraining phenomenon will provide educators, coaches, and clinicians with useful information for developing exercise guidelines, designing in-season conditioning programs, and rehabilitating injuries.

Consequently, the intent of the present study was to evaluate the effects of 8 weeks of strength training and detraining on voluntary strength, flexibility, and vertical jump in children, and to investigate the time course for strength adaptations and retrogressions.

Methods

Subjects

Twenty-four boys and girls between the ages of 7 and 12 volunteered for this study. Since boys and girls demonstrate fairly similar rates of strength gain during pre-adolescence (4), they were combined in this study. Both the children and their parents were informed about this research project and parental written consent was obtained. The experimental group consisted of 11 boys and

4 girls (M age 10.8 ± 0.4 yrs) who enrolled in this study prior to the recruitment of the control group, which included 3 boys and 6 girls (M age 10.0 ± 0.4 yrs).

Following the completion of a medical history questionnaire, a physician examined the children in order to evaluate musculoskeletal status, document preexisting orthopedic injuries, and assess maturity level based on Tanner stages (27). The experimental group consisted of 13 subjects at Tanner Stage 1 and 2 subjects at Tanner Stage 2; the control group had 8 subjects at Tanner Stage 1 and 1 subject at Tanner Stage 2. There were no significant differences between groups for age or Tanner ratings ($p > 0.05$). No subject had regularly participated in any form of resistance training prior to this study.

The following exclusionary criteria were used: (a) children with a chronic pediatric disease, (b) children with an orthopedic limitation, and (c) children classified as Tanner Stage 3 at the beginning of the study. All volunteers were accepted for participation.

Testing Procedures

Both groups participated in two introductory sessions within a 1-week period prior to the evaluation of their fitness status. During this time they were taught the proper technique on each exercise, and any questions they had about the program were answered. The children performed 1 to 2 sets of each exercise with a very light load and practiced the vertical jump test. All were evaluated before and after the training program as well as midway and following the detraining period. In addition, the performance strength of those in the experimental group was reassessed midway through the training program; however, control group subjects were not tested during this time.

Performance Strength. Each subject's 6-RM was determined on the leg extension and chest press. Child-size dynamic constant resistance equipment (Heartline Fitness Equipment, Gaithersburg, MD) was used for all strength testing and training procedures. After an initial warm-up of 10 submaximal repetitions, the 6-RM was found within 3 to 4 trials and was measured to within 1.4 kg. The maximal weight that could be lifted 6 times with correct form throughout the full range of motion was recorded. Following a 72-hr rest period, the strength testing procedures were repeated. The heaviest 6-RM load lifted on each exercise, on either testing day, was recorded as the child's criterion 6-RM score. Test-retest reliabilities ranged from 0.885 to 0.975 for the chest press and leg extension, respectively.

Motor Performance. Lower body motor performance was evaluated by the vertical jump using previously described procedures (23). The highest jump of 3 trials was recorded.

Flexibility. Lower back and hamstring flexibility were evaluated using the sit and reach test following guidelines suggested by the American Alliance of Health, Physical Education, Recreation and Dance (2).

Strength Training Program

The experimental group trained twice a week on Monday and Wednesday for 8 weeks, under adult supervision. Prior to every strength training class the children did 10 min of calisthenics and stretching, and instruction on the importance of proper form and technique were incorporated into every session. Throughout the study an instructor-to-subject ratio of at least 1 to 4 was maintained at all times.

During the first 4 weeks of the training program the children did 1 submaximal warm-up set of 10 repetitions followed by 2 sets of 6 repetitions on the primary (leg extension and chest press) and secondary (leg curl, overhead press, and bicep curl) exercises with a rest period of approximately 1 min between sets. Repetitions were continued in a given set until voluntary muscular fatigue. During the final 4 weeks of training, the children performed 3 sets of 6 repetitions on the primary exercises and continued to perform 2 sets of 6 repetitions on the secondary exercises. The predetermined 6-RM load was used to train the primary muscle groups, namely the quadriceps and pectorals, whereas initial training loads for the secondary exercises were determined on a trial and error basis during the 1st week of training.

When a subject was able to do 8 repetitions on the last set using the correct form, the resistance was increased by 5 to 10% and the repetitions were decreased to 6. During the 4th week of training, each child's 6-RM was redetermined on the primary exercises and training loads were adjusted as needed. In addition to the secondary exercises, the children did 2 or 3 sets of 10 to 20 repetitions on two accessory exercises (abdominal curls and bent-knee leg raises) in order to provide a general conditioning effect.

The children exercised with a partner and took turns at each station until both partners completed the prescribed number of sets. The order of exercises changed every session due to administrative concerns. The children were taught how to record their data on workout logs and did so throughout the training period. The instructors reviewed the workout logs daily and made adjustments in training loads and repetitions if necessary.

No form of resistance training was allowed outside the supervised research setting, and no control group subjects strength trained during the study. However, both groups were permitted to partake in school-based physical education classes and organized sport activities throughout the study. During the training period, 10 children in the experimental group and 5 in the control group took part in organized sports (primarily baseball, soccer, or swimming) at least twice a week.

Detraining Period

Following the 8-week exercise program, the experimental group stopped strength training for 8 weeks in or-

der to provide a model from which the effects of detraining could be evaluated. During this period, 8 children in the experimental group and 5 in the control group participated in organized sports (primarily football, soccer, and basketball) at least twice a week.

Statistical Analysis

Data are reported as mean $\pm$ standard error (SE). ANOVA procedures with time as the repeated measure were employed to determine the significance of the effect of strength training on the dependent variables. The statistical package used was Statview 4.1. If significance was found, post hoc comparisons were performed using the least-significance difference test. Selected strength gain interactions were examined using paired *t* tests. The level of significance was set at $p < 0.05$.

Results

All subjects completed the study according to the aforementioned methodology. The 15 strength training subjects averaged 93% attendance and no injuries occurred from the strength training program. There were no significant differences in height or weight between groups either before or after the training and detraining periods. However, significant main effects for time, indicative of growth, were noted for height and weight (Table 1).

Effects of Training on Performance Strength

Prior to the training period there were no significant differences in upper and lower body strength between groups. Training resulted in significant increases in 6-RM leg extension (53.5%) and chest press (41.1%)

Table 1
Mean Changes ($\pm$ SE) in Physical Characteristics
and Fitness Measures of Subjects

	Training			Detraining		
	Pre	Post	Δ_1	Mid	Post	Δ_2
<i>Experimental Group</i>						
Height (cm)	143.6	144.7		145.1	145.4*	0.7
	± 2.0	± 2.0		± 2.0	± 2.0	
Weight (kg)	43.6	44.5	0.9	44.4	44.9*	0.4
	± 3.0	± 3.0		± 3.0	± 3.0	
Flexibil. (cm)	-0.25	2.6	2.9	2.0	1.2*	-1.4
	± 2.1	± 1.8		± 1.8	± 1.7	
Vert. jump (cm)	23.5	24.9	.4	25.3	24.3*	-0.6
	± 1.4	± 1.5		± 1.5	± 1.4	
<i>Control Group</i>						
Height (cm)	136.5	137.6		138.6	139.1*	1.5
	± 3.1	± 2.9		± 3.0	± 3.1	
Weight (kg)	36.0	36.1	0.1	36.4	36.8*	0.7
	± 4.9	± 4.8		± 4.7	± 4.8	
Flexibil. (cm)	6.8	7.2	0.4	7.8	7.3*	0.1
	± 2.8	± 2.8		± 2.4	± 2.6	
Vert. jump (cm)	24.6	25.1	0.5	25.3	25.6*	0.5
	± 1.3	± 1.5		± 1.6	± 2.0	

Δ_1 = Posttraining-Pretraining; Δ_2 = Postdetraining-Posttraining.

*Main effect for time, $p < 0.05$.

strength, whereas gains for the control group were 6.4 and 9.5%, respectively (Figure 1). For the experimental group, significant gains in leg extension and chest press strength occurred during both the first 4-week phase (17.6 and 16.8%, respectively) and the second 4-week phase (35.9 and 24.3%, respectively) of training. Further analysis revealed significantly greater gains in strength during the second phase of training for both strength tests. Control group strength gains, indicative of growth and activity, were significantly less than those of the experimental group at the end of the training period.

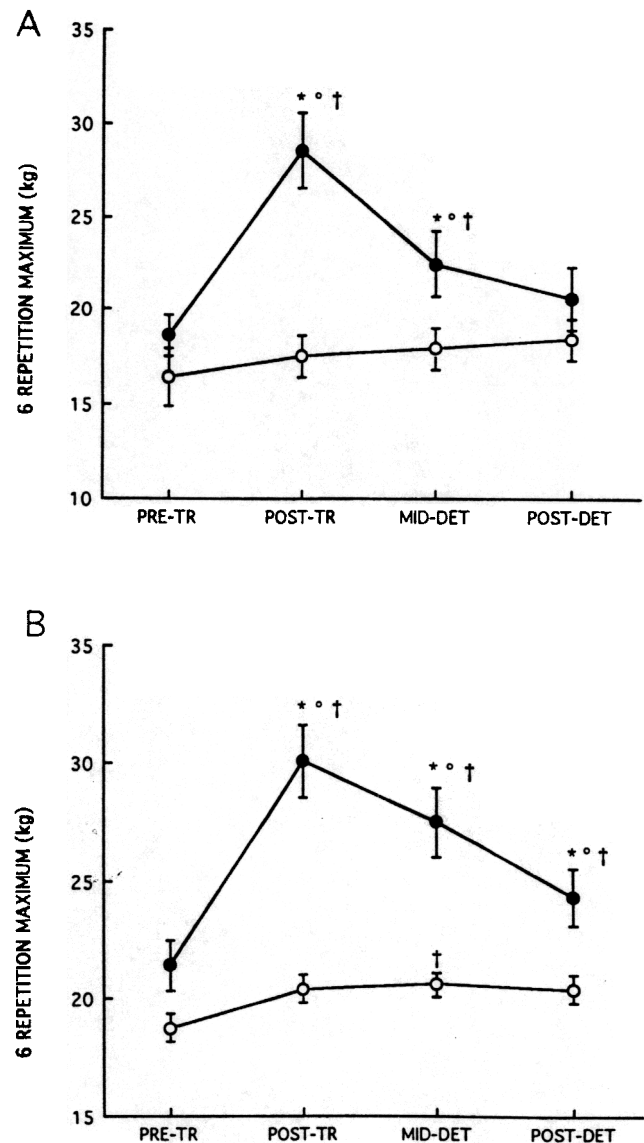


Figure 1. Absolute changes in strength for the (a) leg extension and (b) chest press pretraining (PRE-TR), posttraining (POST-TR), mid-detraining (MID-DET), and postdetraining (POST-DET). Open and filled circles represent mean $\pm$ SE for control ($n = 9$) and experimental ($n = 15$) groups, respectively. Effect significant at $p < 0.05$. Significantly different from: *control value; $\circ$ respective previous value; $\dagger$ respective pretraining value.

Effects of Detraining on Performance Strength

For the experimental group, 8 weeks of detraining led to significant losses of leg extension (-28.1%) and chest press (-19.3%) strength; control group strength scores remained relatively unremarkable (Figure 1). During the first 4 weeks of the detraining period there were significant decreases in strength for the leg extension (-21.3%) and chest press (-8.9%), albeit experimental group values remained significantly higher than control group values. During the second 4 weeks of detraining, leg extension and chest press strength decreased 6.8 and 10.4%, respectively, although only the chest press strength loss was significant. Following the 8-week detraining period, the chest press strength of the experimental group remained significantly greater than that of the control group; however, there was no significant difference in leg extension strength between groups.

Flexibility and Vertical Jump

Changes in flexibility and vertical jump are shown in Table 1. Before training there were no significant differences between groups for the vertical jump. However, the control group was significantly more flexible than the experimental group. Significant main effects for time, indicative of growth and activity, were found for both variables throughout the study period.

Discussion

Individuals who participate in strength training programs often undergo periods of reduced training or inactivity due to program design factors, injury rehabilitation, extended travel plans, busy schedules, or decreased motivation. In adult populations, detraining periods lasting several weeks have been associated with a reduction in strength (14, 26) and muscle fiber area (13, 17); similar findings have been reported in children (6, 15, 24).

In the present study, strength performances on the 6-RM leg extension and chest press increased throughout the training period, then regressed toward untrained control group values during the detraining period, suggesting that strength gains in children are transient and reversible.

The 8 weeks of progressive strength training in this study significantly improved 6-RM chest press and leg extension strength in boys and girls between the ages of 7 and 12 (Tanner Stages 1 and 2 of sexual maturation). The absolute increase of 8.8 kg in chest press strength was between reported increases of 5.2 kg (21) and 10.4 kg (31) for the same exercise in children. The relative increases in chest press (41.1%) and leg extension (53.5%) strength were consistent with other studies involving children (11, 19, 21, 24, 31) and adults (12, 21).

Using similar age groups and study designs, Sailors and Berg (21) reported 5-RM bench press and squat gains of 19.6 and 52.3%, respectively, whereas Faigenbaum et al. (11) reported 10-RM chest press and

leg extension strength gains of 64.1 and 64.5%, respectively. In both studies, subjects participated in 8 weeks of progressive strength training, but the training frequencies varied between twice (11) and thrice (21) weekly.

Thus, direct comparisons between investigations employing different training frequencies are limited. Nevertheless, the magnitude of strength gain observed in the present study (mean 47.3% for the two motions tested) was consistent with or greater than the typical response from 3-day-per-week programs. It is possible, however, that higher training frequencies are more important after the initial adaptation period.

Significant gains in leg extension and chest press strength were evident during both phases of training, although control group comparisons were not available midtraining. The magnitude and rate of strength gain were significantly greater during the second 4-week phase of training whereas other studies involving children (19) and adults (9) have typically noted more rapid rates of strength improvement during the early phase of training. In the present study, however, the greater gains in strength during the latter 4 weeks of training may be due to the increased volume of training during this period.

Since neuromuscular adaptations, including improved motor skill coordination, are partly responsible for strength changes with resistance training in children (19, 22), the substantial gains in strength in the present study were anticipated because of the regular instructional sessions focusing on proper breathing, correct form, and safe body mechanics. Moreover, it is possible that the upper body muscles were at a higher level of conditioning than the knee extensors at the beginning of the study since the strength gains were 12.4% greater for the leg extension as compared to the chest press.

Although upper body strength in American children reportedly has declined for more than two decades (20), the subjects' prior involvement in sports and activities that specifically trained the upper body (e.g., swimming) may help explain this atypical finding.

Despite favorable comments from parents and strength-trained subjects, training did not significantly improve flexibility or vertical jump measures as compared to the control group. Gains in various motor skills have been observed in children who participated in a strength training program (29, 33), although the transfer of the training effect to nonspecific performance measures was not noted in this study. Nevertheless, anecdotal comments from parents suggested that the effects of the training program extended beyond improvements in strength and likely included enhanced sports performance and improved attitudes toward fitness.

Our results confirm the findings of other studies involving adults (14, 26) and children (6, 15, 24) which reported decreases in strength following the cessation of various resistance training programs. In this study, 8

weeks of detraining led to rapid and significant decreases in both leg extension (-28.1%) and chest press (-19.3%) performance while strength measures for the control group either increased slightly or remained relatively unchanged. The magnitude of strength loss during detraining averaged 3.0% a week, which is substantially greater than the weekly detraining response observed in other children.

Sewall and Micheli (24) observed small decreases (mean -1.4% a week over 9 weeks) compared to posttraining results in 3 of 4 strength measures following a detraining period. However, one strength measure increased 65% and control group strength changes were not assessed during this period. Following 8 weeks of detraining, Blimkie et al. (6) and Isaacs et al. (15) observed decreases in various training-induced strength gains in prepubescent boys (6) and girls (15); however, details of the detraining responses were not reported in those studies.

Based on limited research, it appears that selected training-induced strength gains in children are transient and relapse toward untrained control group values during the detraining period. Despite a 53.5% increase in training-induced leg extension strength in this study, there was no significant difference in leg strength between groups by the end of the detraining period. Similarly, the difference in chest press strength between groups at the end of the detraining period was remarkably narrower than posttraining measures. These findings are consistent with the model proposed by Blimkie (5) which outlines the effects of growth, resistance training, maintenance training, and detraining on strength development during childhood.

In the present study, leg extension strength gains attained during the training period rapidly and significantly decreased during the first 4 weeks of detraining (-21.3%), then continued to decrease at a slower rate during the second 4-week phase (-6.8%). Conversely, chest press strength gains significantly decreased at a more even pace, with losses of -8.9 and -10.4% reported during the first and second detraining phases, respectively.

Following 4 weeks of detraining, both strength measures remained significantly higher in the experimental group than in the control group. Although the magnitude of the initial strength gain and the duration of detraining may be partly responsible for the degree of strength regression (5), other factors may also be important. No significant correlations were observed between initial 6-RM strength and strength loss for the chest press and leg extension ($r = 0.23$ and 0.33 , respectively).

Additional forces from activities and sports that place demands on the musculature of the upper and lower body must also be considered. In a study of college football players who had previously participated in an off-season strength training program, Campbell (7) reported an increase in isometric elbow flexion strength during spring

football practice (presumably a form of detraining since resistance training was not performed), while isometric leg extension strength decreased significantly. Campbell suggested that weight-bearing activities and sport-specific stresses to the lower body musculature may have contributed to the decrease in leg strength.

Although speculative, it seems possible that the sports and activities (e.g., football and soccer) undertaken throughout the detraining period in the present study may have been partly responsible for the rapid decrease in leg extension strength as compared to chest press measures.

Practical Applications

The results of this study suggest that children can increase their strength in response to a short-term, progressive resistance training program, but the gains are largely impermanent and begin to regress toward untrained control group values when the training program stops. Coaches and clinicians who work with children should appreciate the transient nature of the training response when developing in-season conditioning programs and rehabilitation therapies. Based on limited research, the discontinuance of a strength training program—even in the midst of sports conditioning—will likely result in a significant loss of strength.

Unfortunately, the amount of training required to maintain or at least slow the loss of exercise-induced adaptations in children has yet to be determined. In one study involving children, a training program of once a week was not enough to sustain gains achieved during the exercise class (6). Yet, in adult populations, training-induced strength gains were maintained even though training frequency was reduced from twice or thrice weekly to once a week—as long as the exercise intensity was maintained (28). Although periods of detraining are virtually inevitable, a maintenance training program should be developed if training-induced strength gains are to be maintained. Further study and evaluation are needed before specific guidelines can be developed for children.

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