The Effects of Upper Body Resistance Training on Prepubescent Children

Judith A. Siegel, David N. Camaione, and Thomas G. Manfredi

To assess the effects of a group resistance exercise program on prepubescent children, an experimental group of boys \((n=26)\) and girls \((n=24)\), with a mean age of \(8.4 \pm 0.5\) years, participated in 12 weeks of school based training. The program consisted of upper body exercise using hand-held weights, stretch tubing, balls, and self-supported movements. A control group of boys \((n=30)\) and girls \((n=16)\), mean age \(8.6 \pm 0.5\) years, had a free-play period. Boys were significantly stronger than girls on all initial strength evaluations and were taller and had lesser skinfold sums. ANCOVA was used to evaluate pre/post changes in cable tensiometer elbow flexion and extension, right and left handgrip strength, pull-ups, flexed arm hang, sit-ups, sit-and-reach flexibility, and body composition parameters. Following the training period, significantly greater gains were made by the experimental group for right handgrip, flexed arm hang, pull-ups, and flexibility. Greater decreases in sum of skinfolds were also found. Training responses of boys and girls were similar. It was concluded that a group strength training program can be an effective means of increasing fitness levels and improving body composition in both boys and girls of this age.

Children's low fitness scores and increasing fatness have been a continuing problem. Studies of nationwide samples of children have repeatedly confirmed this criticism of our youth, particularly with regard to upper body strength and body composition \((1, 2, 12, 22)\). Of the girls from ages 6 to 17 who were tested in the National Child and Youth Fitness Study (NCYFS) \((23)\), 60% could not perform one chin-up. The problem appears to be getting worse, with greater numbers of children scoring below the 50th percentile when data from 1985 were compared with the values for 1975 for chin-ups and flexed arm hang \((23)\). When recent data were compared to skinfold measurements from 20 years ago, increases were found in the number of children, ages 6 to 11 and ages 12 to 17 years, who were classified as obese and "super-obese."

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High levels of body fatness and low upper body strength have been found on preparticipation exams for children’s sport programs (18). Increases in both the occurrence and incidence of sports injuries in children are strongly suspected as an explanation for increases in total number of sport-related injuries (14). Preconditioning has been recommended for young athletes to prevent injury (14, 18). Fleck and Falkel (6) pointed out that the same physiological mechanisms that respond to resistance training also aid in prevention of injuries, namely an increase in muscular strength and connective tissue and a decrease in body fat.

Recent studies have reported significant strength gains for prepubescents following resistance training (11, 20, 24, 25, 28, 29). However, several factors make the programs used by these researchers inappropriate for schools or other large groups. Equipment made for adults or Olympic lifting techniques that require complex coordination are the things that provided the training stimulus. Training responses of young males and females were not compared. In addition, body composition results were confusing. Both greater (24) and lesser weight gain (25) have been reported for experimental groups compared to controls.

The purpose of this study was to determine the effects of upper body resistance training on muscular strength and endurance and body composition in prepubescent boys and girls compared to a free-play program.

Methods

Subjects
All children in the third grade of two elementary schools in a suburban town in the Northeast were offered an opportunity to participate in the study. Informed consent was obtained from students and their parents for in-school testing. An activity questionnaire was filled out by the parents concerning the number of hours each week their child spent in sport-related activities during the intervention period.

Anthropometric and Body Composition Measurements
Chronological age was measured in months. Seven skinfold measurements were taken including triceps, biceps, subscapular, pectoralis, abdominal, iliac crest, and anterior thigh using the methodology of Pollock, Schmidt, and Jackson (21). Height, weight, and waist circumference were assessed using the NCYFS methodology (23). Upper arm and chest circumferences were measured using a Gulick tape. The upper arm circumference was taken at the site of the triceps skinfold. These anthropometric measurements were taken before and after the intervention period by the same researchers.

Strength, Endurance, and Flexibility
Pretest and posttest muscular strength and endurance measurements included the number of sit-ups that could be completed in 1 minute and the number of chin-ups that could be completed using protocols from NCYFS (23). The number of seconds a flexed arm hang was held was measured according to the President’s Council on Physical Fitness Study (PCPFS) protocol (22). The strength of the right and left handgrip was measured in kilograms on a Lafayette dynamometer. Three trials were given and the highest value was recorded. Maximal bilateral
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- Cable tensiometer flexion and extension were performed on a Chatillon tensiometer. The child was supine on a plinth and, with the aid of a goniometer, the elbows were stabilized at 90°. Three readings were taken and the highest was used as a maximal effort. Flexibility of the hamstring group and low back muscle was measured using a sit-and-reach protocol from NCYFS (23).

Programs

Children in the control group had a half-hour free play period which was part of the normal school routine. Activities during that time included eating snacks, socializing, kickball, jump rope, and spontaneous play. Children in the experimental group had a half-hour program of resistance exercise concentrating on the upper body on Monday, Wednesday, and Friday for 12 weeks. The training followed as closely as possible the recommendations of the National Strength and Conditioning Association’s position paper on the Conditioning of Prepubescents (17) and those of Micheli (13).

Three formats were used to provide interest and variety, a need expressed by Totten (27). The obstacle course used upper body self-supported locomotor movements (i.e., wheelbarrow, sealwalk, crabwalk, etc.). A choreographed weight routine used tennis ball cans or detergent bottles filled with sand. Weights of 2.5, 3.0, 3.5, 4.0, and 4.5 lb were offered. The third format was circuit training using various types of accessories as resistance, tennis balls for squeezing, and strips of rubber tire to pull. Each session began with a 3-minute warm-up and ended with instructor-assisted chin-ups and stretching. The work periods were continuous during the choreographed weight routine and in the other two formats; 30 seconds of work alternated with 30 seconds of rest, progressing to 45 seconds of work and 15 seconds of rest. Music with a strong beat was used at each session.

Both groups had physical education classes during the training period. The children in the experimental group had a single half-hour class each week and those in the control group had two such classes. A skill-building curriculum using the same elements was common to both programs.

Results

Subjects

Complete sets of data were obtained from 96 students, 50 in the experimental group (26 boys, 24 girls) and 46 in the control group (30 boys, 16 girls). This accounted for 83% of the third grade population at the experimental school and 79% at the control school. Table 1 shows the status of the experimental and control groups of boys and girls with regard to physical characteristics at the start of the study. Analysis of variance was used to evaluate differences between the experimental and control groups and between the sexes. There were no significant differences between the groups with respect to any of the descriptive variables. However, there were important differences between the sexes. The boys were taller (132.2 ± 6.0 cm vs. 172.2 ± 5.8 cm) and significantly leaner. Mean skin-fold sums of the seven sites were 48.5 ± 22.3 mm for the boys and 62.9 ± 31.4 mm for the girls. This resulted in a mean value for predicted percent body fat of 11.6% for the boys and 17.3% for the girls, using equations by Lohman (10) based on the sum of triceps and subscapular skinfolds.
### Table 1

Descriptive Characteristics of Third Grade Boys and Girls
Before and After Training Period

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Experimental boys (n = 26)</th>
<th>Control boys (n = 30)</th>
<th>Experimental girls (n = 24)</th>
<th>Control girls (n = 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
<td>Pretest</td>
<td>Posttest</td>
</tr>
<tr>
<td>Age (mo)</td>
<td>100.4 ± 5.0</td>
<td>103.4 ± 5.0</td>
<td>103.4 ± 5.1</td>
<td>106.4 ± 5.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>132.5 ± 6.0</td>
<td>134.0 ± 6.0</td>
<td>132.3 ± 6.2</td>
<td>132.7 ± 6.0</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>28.8 ± 5.0</td>
<td>29.1 ± 5.0</td>
<td>28.5 ± 4.8</td>
<td>29.3 ± 4.9</td>
</tr>
<tr>
<td>SSK (mm)</td>
<td>51.5 ± 28.2</td>
<td>45.9 ± 23.2</td>
<td>48.9 ± 20.7</td>
<td>50.9 ± 21.5</td>
</tr>
<tr>
<td>SSC (cm)</td>
<td>132.5 ± 20.0</td>
<td>133.9 ± 21.5</td>
<td>139.3 ± 13.0</td>
<td>143.9 ± 11.0</td>
</tr>
<tr>
<td>Percent fat</td>
<td>11.6 ± 5.1</td>
<td>11.5 ± 4.6</td>
<td>11.6 ± 4.0</td>
<td>12.5 ± 5.3</td>
</tr>
</tbody>
</table>

Values are standard deviations.
SSK = sum of 7 skinfolds; SSC = sum of 3 circumferences. Percent fat based on equations by Lohman (1986).

*Pretest values, *<.05 boys vs. girls; *Pre/post differences, *<.05, experimental vs. control group.
Table 2
Strength and Flexibility Assessments of Boys and Girls
Before and After Training Period

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Experimental boys (n = 26) Pretest</th>
<th>Posttest</th>
<th>Control boys (n = 30) Pretest</th>
<th>Posttest</th>
<th>Experimental girls (n = 24) Pretest</th>
<th>Posttest</th>
<th>Control girls (n = 16) Pretest</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable flex (kg)</td>
<td>11.4 ± 2.3</td>
<td>11.3 ± 2.2</td>
<td>12.1 ± 3.5</td>
<td>11.6 ± 2.3</td>
<td>11.2 ± 1.7</td>
<td>11.8 ± 1.9</td>
<td>11.9 ± 1.8</td>
<td>11.8 ± 2.0</td>
</tr>
<tr>
<td>Cable extensiona (kg)</td>
<td>12.7 ± 2.5</td>
<td>12.6 ± 2.5</td>
<td>11.4 ± 2.7</td>
<td>11.9 ± 2.1</td>
<td>10.1 ± 2.3</td>
<td>9.3 ± 2.0</td>
<td>9.5 ± 2.2</td>
<td>9.9 ± 1.9</td>
</tr>
<tr>
<td>Handgrip (rt)b (kg)</td>
<td>13.4 ± 3.1</td>
<td>14.9 ± 3.3</td>
<td>14.6 ± 3.0</td>
<td>15.0 ± 2.6</td>
<td>10.5 ± 2.0</td>
<td>11.9 ± 2.7</td>
<td>12.1 ± 2.6</td>
<td>12.5 ± 2.6</td>
</tr>
<tr>
<td>Handgrip (lt) (kg)</td>
<td>12.8 ± 3.2</td>
<td>14.0 ± 3.2</td>
<td>13.4 ± 2.6</td>
<td>14.2 ± 2.8</td>
<td>9.9 ± 2.1</td>
<td>11.3 ± 2.6</td>
<td>12.6 ± 3.1</td>
<td>12.6 ± 2.9</td>
</tr>
<tr>
<td>Chin-upsb (no.)</td>
<td>2.4 ± 2.5</td>
<td>3.8 ± 3.6</td>
<td>3.34 ± 3.3</td>
<td>3.2 ± 3.4</td>
<td>1.2 ± 1.6</td>
<td>1.8 ± 1.9</td>
<td>1.9 ± 1.8</td>
<td>1.8 ± 2.0</td>
</tr>
<tr>
<td>Flexed armb hang (sec)</td>
<td>15.3 ± 13.6</td>
<td>21.8 ± 13.3</td>
<td>12.6 ± 9.4</td>
<td>9.1 ± 6.1</td>
<td>8.6 ± 6.0</td>
<td>16.1 ± 15.4</td>
<td>11.0 ± 10.4</td>
<td>7.8 ± 7.4</td>
</tr>
<tr>
<td>Sit-ups (no. in 1 min)</td>
<td>27.7 ± 6.5</td>
<td>28.6 ± 6.1</td>
<td>30.9 ± 5.4</td>
<td>30.0 ± 5.4</td>
<td>23.0 ± 7.5</td>
<td>27.5 ± 5.1</td>
<td>26.2 ± 6.1</td>
<td>29.1 ± 5.1</td>
</tr>
<tr>
<td>Sit-reachb (cm)</td>
<td>24.5 ± 5.1</td>
<td>27.4 ± 5.2</td>
<td>24.1 ± 5.5</td>
<td>23.4 ± 5.6</td>
<td>28.5 ± 6.1</td>
<td>31.1 ± 7.6</td>
<td>28.3 ± 4.7</td>
<td>29.1 ± 6.3</td>
</tr>
</tbody>
</table>

Values are standard deviations.

ap<.02, interaction for changes pre/post; bp<.05, changes pre/post, experimental vs. control.
Strength and Endurance

Table 2 shows the mean values for muscular strength and endurance for the experimental and control groups of boys and girls before and after training. Initial mean values for strength, endurance, and flexibility for males and females were compared using analysis of variance. Boys scored significantly higher than girls on each of the strength measurements. The differences were particularly noticeable on the chin-up and flexed arm hang, where the girls scored 50 and 70%, respectively, of the boys’ scores. On flexibility test the girls’ mean score was significantly higher than the boys’ (28.4±5.5 cm vs. 24.3±5.3 cm).

Training Adaptations

Analysis of covariance was used to investigate the differences with respect to changes between the groups and between the sexes in a 2×2×2 design. The dependent variables were the muscular strength and endurance and flexibility scores. The independent variables were group, sex, and the interaction between group and sex. The covariant was the pretest score. Table 2 shows the results of these comparisons.

There was a significant interaction between group and sex at the p<.02 level for cable tensiometer/extension. There were small differences from pre- to post-testing for the boys in the experimental group (−.1 kg), the boys in the control group (+.5 kg), and the girls in the control group (+.4 kg). The girls in the experimental group decreased sharply on this measurement (−.8 kg).

There were no other significant interactions, therefore the main effects for group and sex were considered. The changes in strength and endurance were significantly greater for the experimental group compared to the control group for the right handgrip (+1.5 kg vs. +0.3 kg), for chin-ups (+1.0 vs. −0.2), for the flexed arm hang (6.8 sec vs. −3.2 sec), and for the sit-and-reach test (+2.8 cm vs. −0.1 cm). The control group did not show significantly higher increases for any of the muscular strength or endurance scores. The decline in some test scores for the control group should be noted in chin-ups and flexed arm hang. There were no significant differences between boys and girls with respect to changes in muscular strength or endurance or flexibility scores other than the cable tensiometer/extension.

The number of hours per week spent in community sports activity obtained from the questionnaire were added to provide a raw score for each child. This variable was entered into the analysis of covariance after the first covariant, pretest scores. No significant amount of variance in any of the muscular strength or endurance or flexibility scores was accounted for by the child’s activity time.

Body Composition

Analysis of covariance was used to evaluate the changes that took place during the study period. The covariant was the pretest skinfold measurement. The experimental group had significant changes in their mean skinfolds at six of the seven sites compared to the control group. Only the iliac crest did not show this pattern of significance. Mean changes in summed skinfold values (SSK) were therefore significantly less for the experimental group compared to the controls. The experimental group decreased in sum of skinfolds from a mean of 57.3±30.3 mm to
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54.1 ± 27.6 mm. The control group increased from a mean value of 51.4 ± 23.5 mm to 53.3 ± 23.3 mm.

Estimates of percent body fat decreased significantly in the experimental group compared to the control group. The experimental group decreased 2.3% to a mean of 12.8 ± 4.9% fat and the control group increased by 1.3% to a mean of 14.0 ± 4.5% fat. Changes in body weight did not show a significant difference between the groups, nor were there significant changes in any of the circumference measurements or in the circumference sum. However, there was a tendency for the experimental group toward greater height gain (+1.5 cm. vs. +0.6 cm). There were no significant differences between boys and girls with respect to changes in any of the anthropometric variables.

Discussion

**Strength, Endurance, and Flexibility Measures**

Differences in strength between males and females of this age are consistent with those found by other researchers (16, 24, 25). It has been observed that much of this difference is due to discrepancies in size (height and weight) (16), as well as the increased fatness in girls from an early age (9, 19) and greater motivation on the part of boys (26).

It was the major task of this study to determine whether a school based resistance training program of 1/2 hour, 3 days a week, would increase upper body strength and endurance in groups of prepubescent boys and girls. Other researchers have demonstrated increased strength in response to resistance exercise in the prepubescent age group (11, 20, 24, 25, 28, 29). However, it was important to show that a practical, cost effective method of resistance training could provide the benefits of improved muscular fitness to large groups of children.

The training programs used in the above studies were markedly different from one another, but none involved a large investment of time on the part of the subjects. The boys in the Weltman et al. (29) study worked on strength training for 30 seconds of maximum effort, up to 30 reciprocal contractions, alternating with 30 seconds of rest for 30 minutes. Roughly 60% of the time was spent on upper body exercise. Total work time for upper body at each session was approximately 18 minutes, continuing for 14 weeks. In the Sewall and Micheli study (25) the boys exercised for 9 weeks, performing three sets of three exercises at 50, 80, and 100% of a 10-repetition maximum, a total exercise time of 5 to 7 minutes per session. In the present study the children worked continuously for approximately 20 minutes each session, concentrating on upper body resistance exercise, three times per week for 12 weeks. Each study was able to demonstrate significant increases in strength and/or endurance for a relatively small investment of time.

Except for the decrease in the mean value of the girls in the experimental group on the cable tensiometer/extension, there were no significant differences in strength endurance or flexibility gains between boys and girls. This is in agreement with the work of Cureton et al. (4) and Miller et al. (15), who found that men and women made similar relative strength gains following a resistance training program.
These studies contradict the position held in the past that children would not gain in strength before the onset of puberty and a marked increase in the level of circulating androgens. The view that resistance training is an effective method for increasing strength in prepubescents is further supported by the work of Pfeiffer and Francis (20), who found no differences among prepubescent, pubescent, and postpubescent children with regard to percentage increases in strength following a resistance training period.

It was of interest that there was a significant increase in the right handgrip, but not the left one, in the experimental group compared to the controls. A close examination of the data shows that the gain in handgrip by the experimental group was similar on the right and left side, \(+1.5\) kg and \(+1.3\) kg, respectively. However, the control group showed a larger growth in the strength of the left grip measurement, \(+1.1\) kg, than in the right hand grip, \(+0.3\) kg.

**Body Composition**

A decrease in body fatness as a response to training has not been reported by other researchers of resistance exercise in prepubescents. However, Wilmore (30) reported decreases in percent body fat and skinfolds in both men and women following short-term resistance training. Perhaps the decrease in skinfold measurements found in this study was the result of nearly continuous exercise during the half-hour training periods.

The changes in skinfold size for the experimental group were not large, and probably by themselves would not have been significant when comparing pre- to posttesting. However, the control group increased in skinfold measurements. Increases in skinfold thickness as children mature is expected, as shown by the cross-sectional data of Johnson, Fulwood, and Abraham (8) or NCYFS (23). In addition, during the 3-month study period the New England weather, the change from Daylight Savings to Standard time, and particularly the non-physical nature of school activities would provide for less large muscle activity than during the summer. Increasing fatness as a result of inactivity can easily occur, according to Johnson, Burke, and Mayer (9). Since the problem of increased obesity in American children has been cause for alarm by some (7), finding a decrease in skinfolds in a school based program was important.

There was a tendency toward greater height gains for children in the experimental group compared to those in the control group. Weltman et al. (29) reported a similar tendency. Significant growth differences were reported earlier by Ekblom (5) in adolescent boys who trained.

**Sport Activity**

No significant amount of the variance in muscular strength and endurance or flexibility scores could be accounted for by the child’s sport activity time. Ross et al. (23) found that children who participated in community sport activities had better fitness scores. However, that research was a cross-sectional study. A significant correlation between sport activity time and fitness scores does not mean that increased fitness is caused by the sport activities. Self-selection, favoring the talented athlete or the child from an affluent family, can operate to continue outside of school activities for sufficient time to develop the sport skills necessary to maintain high fitness levels.
Conclusions

This study indicates that a school based program of group resistance training can be an effective means for increasing right handgrip, flexibility, and upper body muscular endurance in prepubescent boys and girls. It was also concluded that body fatness, as measured by skinfolds, can be reduced in boys and girls of this age using a program of resistance exercise, 1/2 hour 3 days per week for 12 weeks, compared to free play or to community sport programs.

References