Effects of Different Resistance Training Protocols on Upper-Body Strength and Endurance Development in Children

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ABSTRACT
This study examined the effects of 4 different resistance training protocols on upper-body strength and local muscle endurance development in children. Untrained boys and girls (mean ± SD age, 8.1 ± 1.6 years) trained twice per week for 8 weeks using child-sized weight machines and medicine balls weighing 1–2.5 kg. In addition to general conditioning exercises, subjects in each exercise group performed 1 set of the following exercise protocols for upper-body conditioning: 6–8 repetitions with a heavy load on the chest press exercise (HL, n = 15); 13–15 repetitions with a moderate load on the chest press exercise (ML, n = 16); 6–8 repetitions with a heavy load on the chest press exercise immediately followed by 6–8 medicine ball chest passes (CX, n = 12); or 13–15 medicine ball chest passes (MB, n = 11). Twelve children served as nontraining controls (CT). After training, only the ML and CX groups demonstrated significant (p < 0.05) improvements in 1RM chest press strength (16.8% and 16.3%, respectively) as compared with the CT group. Local muscle endurance, as determined by the number of repetitions performed posttraining on the chest press exercise with the pretraining 1RM load, significantly increased in the ML group (5.9 ± 3.2 repetitions) and CX group (5.2 ± 3.6 repetitions) as compared with the CT group. In terms of enhancing the upper-body strength and local muscle endurance of untrained children, these findings favor the prescription of higher-repetition training protocols during the initial adaptation period.

Key Words: strength training, weight training, complex training, youth, preadolescents


Introduction
Research conducted over the past decade provides compelling evidence that children can increase their muscle strength above and beyond growth and maturation by participating in a resistance training program (5, 12). Despite the previously held belief that children could not benefit from resistance training due to inadequate levels of circulating androgens, medical and fitness organizations now support children’s participation in appropriately designed and competently supervised youth resistance training programs (2, 3, 7). In addition to increasing muscle strength, improvements in motor performance skills, cardiorespiratory fitness, bone mineral density, and body composition have been observed in children who resistance train (11, 14, 15, 18, 22).

Different combinations of sets and repetitions and a variety of training modalities have proven to be safe and effective for children, although the training intensity (i.e., load or resistance used) seems to be one of the more important variables. In adult populations, it appears that the use of heavy loads (e.g., repetition maximum [RM] loads of 6 or less) have the greatest effect on muscle strength, whereas lighter resistances (e.g., RM loads of 20 or more) have the greatest effect on local muscle endurance (13). In general, it appears that the relationship between training intensity and the magnitude of strength change in adults is linear. However, limited data suggest that children may respond differently to resistance training protocols. For example, the largest reported strength gain in children after a short-term resistance training program has resulted from a relatively high-repetition training protocol (11).

It has been recommended that children perform at least 1 set of 6–15 repetitions on a variety of upper- and lower-body exercises at least 2–3 times per week (7). However, more specific recommendations regarding the most effective resistance training protocol for children would be useful to physical educators and youth coaches. In particular, since upper-body muscle
Based on comparisons of groups using analysis of variance. Adaptations in healthy children. The question of what resistance training protocol optimizes gains in upper-body strength and local muscle endurance development in children during the initial adaptation period. Therefore, the primary purpose of this investigation was to examine the effects of 4 different resistance training protocols on upper-body performance. Additional data are needed to gain insights into the effects of resistance training on upper-body components of health-related physical fitness (1, 17), there is a distinct need for a greater understanding of resistance training programs and were tested before and after training on selected measures of strength and local muscle endurance in children during the initial adaptation period. Therefore, the primary purpose of this investigation was to examine the effects of 4 different resistance training protocols on upper-body performance adaptations in healthy children.

Methods

Approach to the Problem and Experimental Design

Based on the hypothesis that children respond better to higher-repetition training protocols during the initial adaptation period, this research study was designed to assess children’s physiologic adaptations (i.e., muscle strength and local muscle endurance) to 4 different resistance training protocols with different loading schemes. Untrained children participated in 1 of 4 resistance training programs and were tested before and after training on selected measures of strength and local muscle endurance. An age-matched group of children served as controls. Subsequent analyses of pretraining and posttraining measures allowed us to evaluate changes in strength and local muscle endurance in response to the various training programs.

Subjects

Sixty-six children (44 boys and 22 girls) aged 5.2–11.8 years volunteered to participate in this study. Both the children and their parents were informed about the nature of this project and completed health history questionnaires. The following exclusionary criteria were used: (a) children with a chronic pediatric disease, (b) children with an orthopedic limitation, and (c) children older than 12 years of age at the beginning of the study. All volunteers were accepted for participation, and no volunteer had any prior experience with resistance training. Informed consent was obtained from the parents and their children. Descriptive characteristics of the subjects are presented by group in Table 1.

Due to the large number of subjects in this study and the size of the training area, this study protocol involved 2 data collection phases. This approach was necessary to maintain a safe training environment, high-quality instruction, and a low instructor to subject ratio (less than 1:4). Throughout the study period, subjects typically exercised in groups of 8–10, and all exercise sessions were supervised by 1 exercise physiologist, 1 youth fitness instructor, and 1 or 2 exercise physiology student interns. All training sessions took place after school in a YMCA youth fitness center that was used exclusively by the subjects in this study on designated training days. During each training session, instructors reviewed proper exercise technique and made appropriate adjustments in training resistance and repetitions. During phase 1, subjects were randomly assigned to a heavy-load, low-repetition training group (HL; girls, n = 5; boys, n = 10) or a moderate-load, high-repetition training group (ML; girls, n = 4; boys, n = 12). During this phase, 12 children volunteered to serve as nontraining control subjects (CT; girls, n = 3; boys, n = 9). The results from phase 1 have been published elsewhere (8).

During phase 2, different subjects were randomly assigned to a complex training group that performed a combination of low-repetition, heavy-load training and medicine ball exercises (CX; girls, n = 5; boys, n = 7) or a medicine ball group that performed medicine ball training in lieu of the primary strength exercise (MB; girls, n = 5; boys, n = 6). Complex training is a method of conditioning in which biomechanically comparable strength and plyometric exercises are combined, set for set, within the same exercise session (6), and medicine ball training involves the use of weighted balls and dynamic body movements. Since boys and girls demonstrate fairly similar rates of strength development during preadolescence (4), they were

<table>
<thead>
<tr>
<th></th>
<th>HL (n = 15)</th>
<th>ML (n = 16)</th>
<th>CX (n = 12)</th>
<th>MB (n = 11)</th>
<th>CT (n = 12)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>7.8 ± 1.4</td>
<td>8.5 ± 1.6</td>
<td>8.3 ± 1.2</td>
<td>9.2 ± 1.6</td>
<td>8.6 ± 2.2</td>
<td>0.28</td>
</tr>
<tr>
<td>Age range, y</td>
<td>6.0–10.3</td>
<td>6.0–11.0</td>
<td>6.5–10.8</td>
<td>7.2–11.4</td>
<td>5.2–11.8</td>
<td></td>
</tr>
<tr>
<td>Weight, kg</td>
<td>35.4 ± 8.4</td>
<td>39.8 ± 11.9</td>
<td>32.6 ± 8.6</td>
<td>35.5 ± 10.7</td>
<td>27.7 ± 6.0</td>
<td>0.03</td>
</tr>
<tr>
<td>Height, cm</td>
<td>130.6 ± 8.5</td>
<td>133.0 ± 9.6</td>
<td>129.2 ± 8.2</td>
<td>133.5 ± 10.6</td>
<td>127.4 ± 10.6</td>
<td>0.45</td>
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</tbody>
</table>

* HL = heavy-load, low-repetition training group; ML = moderate-load, high-repetition training group; CX = complex training group; MB = medicine ball training group; CT = control group. Data are presented as mean ± SD. The p values are based on comparisons of groups using analysis of variance.
combined in this study. The influence of each of the 4 resistance training protocols on laboratory indices of upper-body muscle strength and local muscle endurance were assessed by comparing changes between exercise and control groups.

**Testing Procedures**

All subjects participated in 1 introductory session before testing to learn correct exercise technique on the testing equipment, to reduce the influence of any learning effects, and to become familiar with general strength-training guidelines (i.e., controlled movements and proper breathing). Measurements were made with identical equipment positioning using child-sized dynamic constant external resistance (DCER) equipment (Schnell Equipment, Peutenhausen, Germany). All subjects performed 10 minutes of aerobic exercise and stretching before all testing and training procedures.

**Maximum Strength.** Each subject's 1 repetition maximum (RM) strength was determined on the vertical chest press exercise before the start of the program and after 8 weeks of training. On the vertical chest press exercise, subjects were standing erect with their back against the support pad and both hands in a neutral grip position grasping the handles located at chest level. Children were instructed to extend their arms in front of their body until their elbows were about 5° short of full extension (to prevent locking at the elbow joint), then to return to the starting position. Subjects performed 3 submaximal sets before attempting a single repetition with the perceived 1RM load. The 1RM was typically determined within 4–6 trials. Failure was defined as a lift falling short of the full range of motion on at least 2 attempts spaced at least 2 minutes apart. All testing procedures were closely supervised, and uniform encouragement was offered to all subjects. Test-retest reliability in our laboratory for 1RM testing in children is very good: intraclass correlation coefficients range from $R = 0.93$ to $R = 0.98$, depending on the type of exercise (9).

**Local Muscle Endurance.** At the end of the training period, all subjects performed a test of local muscle endurance on the vertical chest press exercise. After a warm-up set of 6 repetitions with a relatively light load (and a 2-minute rest period), subjects attempted to perform as many repetitions as possible with their pretraining 1RM weight. Subjects were told to maintain proper form during this test and were encouraged to perform as many repetitions as possible. The number of repetitions performed to volitional fatigue using the correct form were counted and recorded as criterion values of local muscle endurance.

**Resistance Training Program.** Exercise subjects trained twice per week on nonconsecutive days for 8 weeks. Previous investigations have clearly demonstrated that resistance training twice per week is sufficient for enhancing the muscle strength and local muscle endurance of children (10, 11). Furthermore, resistance training twice per week provides children with the opportunity to participate in other sports and recreational activities. Instructors reviewed proper training procedures on a daily basis, and the children were taught how to record their data on workout logs and did so throughout the study period. Although the primary focus of this study was on the development of upper-body strength and local muscle endurance, for general conditioning purposes, all exercise subjects participated in a resistance training program that consisted of 10 additional exercises (2 body weight exercises [abdominal curl and lower back extension] and 8 DCER exercises [leg press, leg extension, leg curl, hip abduction, pull-over, seated row, abdominal flexion, and front pull-down]). Child-sized strength-training equipment was used for all training sessions.

All resistance training protocols consisted of 1 set per exercise. The last repetition of each set on DCER exercises represented momentary muscle fatigue. Subjects in the HL group performed 6–8 repetitions on all exercises, and subjects in the ML group performed 13–15 repetitions on all exercises. Subjects in the CX group performed 13–15 repetitions on all exercises except on the vertical chest press, on which they performed 6–8 repetitions immediately followed (within 10 seconds) by 6–8 medicine ball chest passes. Subjects in the MB group performed 13–15 repetitions on all exercises; however, instead of the vertical chest press exercise, they performed 13–15 medicine ball chest passes.

During the first week of training, exercise loads were titrated on all DCER exercises to elicit volitional fatigue within the prescribed repetition range. When the desired number of repetitions could be performed, the weight was increased by 5–10%, and the repetitions were decreased to the lower end of the prescribed repetition training range. Throughout the study, all subjects were encouraged to increase the amount of weight lifted within each designated repetition range. If a subject missed a session, the training load was not increased at the returning session. On the body weight exercises, subjects in all groups performed up to 1 set of 15 repetitions.

Presently, no method exists to quantify medicine ball training load/impact force in children. Although the mass of a medicine ball is usually known, once the ball is in motion, the impact force may change considerably depending upon how hard the ball is thrown. Therefore, the medicine ball training program developed for this study was based on previous observations from our youth fitness center. All subjects in the CX and MB groups used a 1-kg polyurethane medicine ball (about the size of a volleyball) during the first 2 weeks of the study. The weight of the medicine ball increased to 2.5 kg (in increments of 0.5 kg every other
week) over the course of the study period. The use of a 1-kg medicine ball at the start of the study and the gradual progression to a 2.5-kg ball by the seventh week of training provided all subjects with an opportunity to perform each repetition explosively and experience success. Each subject was encouraged to throw the medicine ball as hard as possible to an instructor, who was standing about 8–10 ft from the subject, who immediately repeated the chest pass exercise. This cycle was repeated for the prescribed number of repetitions. When the weight of the medicine ball increased, the repetitions performed by a subject decreased to the lower end of the prescribed training range. Although subjects in the CX and MB groups performed a different number of repetitions for medicine ball training (6–8 or 13–15 repetitions, respectively), the weight of the medicine ball during a given training session was the same for both groups.

The order of exercises was changed every session to maximize enjoyment for the subjects, and no form of resistance training outside of the research setting was allowed. All children were permitted to participate in school-based physical education classes and recreational activities throughout the study period. Attendance was taken at every session. Subjects in the control group were asked not to participate in any resistance training program during the study period.

Statistical Analyses
Descriptive statistics (means ± SDs) for age, height, and weight were calculated. For baseline comparisons, the 5 groups were compared using a 1-way analysis of variance (ANOVA) to determine if any differences existed before training. A 2-way (group × time) repeated-measures ANOVA was used to detect possible changes occurring over time for the 1RM strength data. In the presence of significant F value, a series of post hoc comparisons were performed to identify where the differences occurred. A 1-way ANOVA was performed posttraining to determine if any differences existed among groups for tests of local muscle endurance. The level of significance was set at p < 0.05. In terms of statistical power, data from our laboratory indicate that the SD in 1RM testing for upper-body strength in children is about 20% (9). Since we would consider a difference in effect size between exercise groups (pairwise comparisons) of 25% (1.25SD) to be important, at least 11 subjects per group were required to achieve 80% power at an alpha level of 0.05 (2-tailed).

Results
Sixty-five of the 66 subjects completed this study according to the aforementioned methodology. One subject in the HL group was unable to complete the study because of a scheduling conflict. Study participants were similar in age, height, and baseline 1RM strength but heterogeneous with respect to weight (Table 1). Average attendance at the training sessions for each of the 4 exercise groups was not less than 92%. Post hoc averaging of training loads indicated that the training stimulus on the chest press exercise for the HL group had been 67.5% of their initial 1RM, whereas the HL and CX groups trained at intensities of 78.9% and 72.6%, respectively, of their initial 1RM. The MB groups did not train on the chest press exercise. During the study period, 6 subjects (40%) in the HL group, 5 subjects (31%) in the ML group, 6 subjects (50%) in the CX group, 4 subjects (36%) in the MB group, and 5 subjects (42%) in the CT (control) group participated regularly in organized sports programs at least twice per week (principally soccer and swimming). No injuries occurred throughout the study period, and all training protocols were well tolerated by the subjects.

Chest press strength gains made by the ML and CX groups were significantly greater than gains made by the CT group (p < 0.05) (Table 2). The strength gains occurring in the MB and HL groups were not significantly different from the strength gains in the CT group, which were attributed to growth and maturation. For these comparisons, the probabilities of making a type II error were 20% and 47%, respectively. Both the ML and CX groups achieved significantly greater gains in chest press local muscle endurance compared with the CT group, whereas gains made by the HL and MB groups were not significantly different from those made by the CT group (Table 3). Gains in chest press local muscle endurance resulting from CX training were also significantly greater than those resulting from MB training.

Table 2. Results for the 1RM chest press tests pretraining and posttraining.†

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretraining, kg</th>
<th>Posttraining, kg</th>
</tr>
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<tbody>
<tr>
<td>HL</td>
<td>24.5 ± 5.9</td>
<td>25.8 ± 6.4*</td>
</tr>
<tr>
<td>ML</td>
<td>25.7 ± 9.1</td>
<td>29.9 ± 9.7*†</td>
</tr>
<tr>
<td>CX</td>
<td>23.8 ± 4.3</td>
<td>27.8 ± 4.1*†</td>
</tr>
<tr>
<td>MB</td>
<td>24.1 ± 3.9</td>
<td>25.8 ± 3.8*</td>
</tr>
<tr>
<td>CT</td>
<td>21.2 ± 5.1</td>
<td>22.1 ± 5.3*</td>
</tr>
</tbody>
</table>

† RM = repetition maximum; HL = heavy-load, low-repetition training group; ML = moderate-load, high-repetition training group; CX = complex training group; MB = medicine ball training group; CT = control group. Data are presented as the mean ± SD.

* Indicates significant difference (p < 0.05) within a group between pretraining and posttraining values.
† Indicates significant difference (p < 0.05) compared with CT.
Table 3. Results for the chest press local muscular endurance tests posttraining.§

<table>
<thead>
<tr>
<th>Group</th>
<th>No. repetitions with pretraining 1RM</th>
</tr>
</thead>
<tbody>
<tr>
<td>HL</td>
<td>3.1 ± 2.5</td>
</tr>
<tr>
<td>ML</td>
<td>5.2 ± 3.6†</td>
</tr>
<tr>
<td>CX</td>
<td>5.9 ± 3.1‡</td>
</tr>
<tr>
<td>MB</td>
<td>3.1 ± 2.7</td>
</tr>
<tr>
<td>CT</td>
<td>1.7 ± 1.1</td>
</tr>
</tbody>
</table>

§ RM = repetition maximum; HL = heavy-load, low repetition training group; ML = moderate-load, high-repetition training group; CX = complex training group; MB = medicine ball training group; CT = control group. Data are presented as mean ± SD.

* Indicates significant difference (p < 0.05) from HL.
† Indicates significant difference (p < 0.05) from CT.
‡ Indicates significant difference (p < 0.05) from MB.

Discussion

Since upper-body muscle strength and local muscle endurance are considered important components of health-related physical fitness in children (1, 17), increasing participation in physical activities that enhance muscle function has been recommended by fitness and sports medicine organizations (2, 3, 7). In this investigation, we provide evidence that higher-repetition training protocols (either strength training or combined strength training and plyometric training) enhance the upper-body strength and local muscle endurance of untrained children more so than other training protocols. These data are important to help identify the most effective exercise prescription for children participating in an introductory resistance training program.

It should be noted that the purpose of this study was to determine for practical purposes the most effective 1-set training protocol for eliciting gains in upper-body strength and local muscle endurance in untrained children who volunteered to participate in an after-school youth fitness program. This investigation did not address the effects of periodized conditioning programs on muscular fitness. Although further study is warranted, it is possible that periodized conditioning programs might provide a better training stimulus for the long-term training of children. Thus the results from this investigation may not be applicable to trained children and young athletes in whom the relationship between training intensity, training volume, and the magnitude of strength gain may be different. The primary outcome measures in this investigation were muscle strength and local muscle endurance.

The results of this study suggest that untrained children can make significant gains in 1RM upper-body strength by participating in a resistance training program. Interestingly, in the present investigation, only the ML and CX groups made strength gains that were significantly greater than those of the CT group (16.3% and 16.8% vs. 4.2%, respectively). In comparison, strength gains made by children in the HL or MB groups were not greater than the CT group gains. Observed strength gains made by the ML and CX groups were somewhat lower than those reported in other short-term studies involving children (10, 11, 19, 22). The absolute increases in 1RM chest press strength that occurred in the ML (4.2 kg) and CX (4.0 kg) groups were also lower than those reported in other short-term investigations involving children (10, 11, 19).

The greater gains in muscle strength in other studies compared with the present investigation may be attributable to the training volume (i.e., the total amount of work performed per training session and per week). It is reasonable to suggest that higher training volumes (e.g., 3 sets of 10–15 repetitions with a moderate load) may result in greater upper-body strength gains in children than programs characterized by lower training volumes. Furthermore, issues related to testing-training specificity may explain in part the relatively small gains in upper-body strength experienced with MB training. Although muscle strength was evaluated by 1RM testing on the same equipment that children in the HL, ML, and CX groups used for training, children in the MB group did not train on the chest press exercise. Even though the chest press exercise and the medicine ball chest pass exercise involve essentially the same muscle groups (i.e., pectoralis major, anterior deltoid, and triceps), medicine ball training was performed with a lighter load and at a faster training velocity. As previously observed in adult populations (21), training adaptations in children may not only be specific to the movement pattern, but also to the velocity of movement.

Consequently, medicine ball training characterized by fast-velocity movements (and a rapid generation of force) may be less likely to induce improvements in 1RM strength when compared with traditional strength-training programs characterized by slow, methodic movements. Although the paucity of “medicine ball” training studies involving children limit any comparisons of our results to previous research, it is intuitively attractive to assume that medicine ball training has the potential to be superior to other modes of conditioning for enhancing speed strength (power) and explosive strength (maximum rate of force development) in children.

Although additional study is warranted, it seems that there may be a threshold level of strength exercise necessary to stimulate gains in upper-body strength in children. Our data show that 1 set of 6–8 repetitions with a heavy load or 1 set of 13–15 repetitions with a
lightweight medicine ball may be suboptimal for enhancing the upper-body strength of children above and beyond growth and maturation. Even though all subjects trained under close supervision with frequent adjustments in training intensity to maintain the desired training stimulus, it appears that higher-repetition training protocols (either with moderate loads or heavy loads combined with medicine ball exercises) result in more favorable changes in upper-body strength during the initial adaptation period. The effects of these training protocols over longer durations has yet to be determined. These findings may be particularly important for young athletes who may need to enhance their muscle strength before participating in sport-specific conditioning programs.

Although not assessed in this study, training-induced gains in children have been attributed primarily to neuromuscular adaptations (e.g., increases in motor unit activation and improvements in motor skill coordination) as opposed to hypertrophic factors (18). Thus it seems reasonable to conclude, although not with complete confidence, that higher-repetition training protocols during the initial adaptation period may provide a better stimulus for enhancing the muscle strength of children. While low-repetition, heavy-load training protocols may optimize strength gains in adults (13), this type of training may not be ideal for untrained children. Higher-repetition training may provide a better opportunity for improved coordination or learning and increased activation of the prime movers (i.e., increased number of motor units recruited and increased discharge frequency). Since children cannot activate their muscles as well as adults in the untrained state (20), higher-repetition training protocols may be ideal for children participating in an introductory resistance training program. Furthermore, complex training may offer additional advantages since this method of conditioning appears to enhance muscle power in adults (6), and it seems reasonable to suggest that children could experience similar benefits, provided the program is appropriately prescribed. Clearly, additional research is needed to explore the effects of different training protocols on the precise neural and mechanical mechanisms than enhance strength and power in children.

As expected, upper-body local muscle endurance improved after 8 weeks of progressive resistance training. However, in the present study, only endurance gains made by the ML and CX groups were significantly greater than gains made by the CT (control) group. Gains made by the ML and CX groups were also significantly greater than those made by the HL group. These findings support the observations of others who reported increases in local muscle endurance in children who participated in a progressive resistance training program (18). While verbal comments from children in this study suggested that they enjoyed medicine ball training, our data indicate that strength training combined with medicine ball training (i.e., complex training) may be more beneficial than medicine ball training alone.

In adult populations, resistance training programs that are designed to maximize strength are not typically as effective in increasing muscle endurance (13). The results from this study suggest that in the short term, high-repetition training (either ML or CX training) may be equally effective in enhancing the muscle strength and local muscle endurance of untrained children. Thus, it seems that children and adults may respond differently to resistance training protocols, and that the relationship between the training stimulus and the response may vary among different populations. Although all training protocols used in this study can be considered safe (i.e., no injuries resulted from any training program), the results suggest that if children begin resistance training with 1 set per exercise, a high number of repetitions (13–15 repetitions) with a moderate load or a low number of repetitions (6–8 repetitions) followed by 6–8 medicine ball exercises should be recommended for upper-body training (assuming that the repetitions on the DCER exercises are performed to the point of temporary fatigue). Is it possible that more frequent training sessions or longer training periods may be needed to observe changes in upper-body strength in response to HL and MB training, however.

In the past, it has been difficult to compare the effects of selected resistance training protocols in children because of differences in program design, study duration, and training methodologies. While the results from this investigation confirm the results of previous studies that reported significant gains in muscle strength in children after resistance training, a novel finding from the present study was the magnitude of upper-body muscle strength and local muscle endurance development resulting from ML and CX training as compared with that of other groups. Additionally, these data highlight the potential value of complex training, which appears to be a safe, effective, and efficient means of training healthy children.

A limitation of this study is that some of the subjects performed power training, but we did not perform a power test. Future studies should be designed to identify training protocols that enhance muscle power in children. Another concern is that the weight of the control group was significantly less than that of the exercise groups. In theory, this may complicate the interpretation of the research findings since a given absolute increase in strength may represent a smaller relative increase in a heavier child, who is likely to begin training with a greater initial level of absolute strength. However, there was no significant difference in 1RM chest press strength at the start of the training period. Also, since we did not assess biologic matu-
rational at the start of the study period, it is possible that some of the older subjects may have entered their pubertal years or adolescence. Thus, it cannot be stated with complete confidence that all of the subjects were preadolescents. However, for the purpose of this study, we contend that this limitation is minor because relative strength gains achieved during preadolescence are comparable with relative gains observed during adolescence (16). Lastly, since this investigation addresses only the initial phase of adaptation in previously untrained children, it is possible that differences between selected training protocols may not be evident due to the short-term nature of this study.

Practical Applications

The results from our investigation suggest that children can enhance their upper-body strength and local muscle endurance by participating in a progressive resistance training program. While training-induced improvements in muscle performance are a function of many factors (e.g., program design and quality of instruction), our data indicate that during the initial adaptation period, beginning with a high-repetition training protocol (either with a moderate load or a heavy load combined with medicine ball training) is more effective than other training protocols in untrained children. Although a greater training stimulus may be needed to elicit additional adaptations in trained children, beginning an upper-body resistance training program for children with a single set will allow for positive changes in muscle performance. The results from this study suggest that training programs designed to optimize strength development in adults may not be equally effective in untrained younger populations. Finally, long-term studies are needed to explore the effects of periodized resistance training programs on selected performance measures in children.

References