The Effect of Duration of Resistance Training Interventions in Children Who Are Overweight Or Obese

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Abstract

Sgro, M, McGuigan, MR, Pettigrew, S, and Newton, RU. The effect of duration of resistance training interventions in children who are overweight or obese. *J Strength Cond Res* 23(4): 1263–1270, 2009–The purpose of this study was to investigate the effects of different durations of resistance training on body composition and power in children. The study was a 24-week longitudinal design involving 31 preadolescent children who were overweight or obese (ages 7–12 years), divided into 3 groups and resistance trained 3 times per week. Group 8 (G8) trained for 8 weeks, group 16 (G16) trained for 16 weeks, and group 24 (G24) trained for 24 weeks. All participants were measured at weeks 0, 8, 16, and 24 for body composition and power. Subjects in G8 and G16 continued to be tested during the testing weeks after cessation of their training programs. Body composition and bone mineral content were measured by dual-energy X-ray absorptiometry. Significant improvements in body composition were seen in the initial 8-week training phase, and these improvements were maintained for the subsequent 16 weeks. Significant changes in percent body fat (~5–7%) were observed at 8 weeks in all 3 groups. Total fat mass decreased significantly at week 8 in G16 and G24 (5.9%). By week 24, total fat mass was significantly reduced by 8.1% in G24. Significant improvements were observed in static jump power, which improved by 10.5% at week 16 in G24. These results suggest that an 8-week resistance training program is sufficient time to significantly change body composition, strength, and power measures in children who are overweight or obese. However, further improvements are realized with longer-duration resistance training programs. On cessation of the training programs, the G8 and G16 groups maintained the benefits of the exercise program until the end of the study period.

Key Words strength training, obesity, exercise

Introduction

Childhood and adolescent obesity is a significant problem in Australia and is worsening. Between 1985 and 1997, the proportion of overweight Australian children ages 7–15 years increased by almost 70% (3). Around 20%–25% of Australian children and adolescents are overweight or obese (3,20). This is a significant social problem that needs to be addressed via a range of diverse strategies. Research has shown that obesity during childhood substantially increases the risk of orthopedic, metabolic, respiratory, and psychological disorders (1,4). Associated with the rising levels of pediatric obesity are a series of health issues, including cardiovascular disease (1,4). This is exacerbated by findings that children who are overweight are at a greater risk of remaining overweight as adults compared with their nonobese counterparts (4,5).

Most research studies have suggested that increased levels of physical activity, combined with improved nutrition, can improve body composition and overall health of children who are obese or overweight (22). However, the majority of these programs, which use aerobic exercise modalities, may not be well tolerated by overweight and obese children because of their additional body fat mass compared with their nonobese counterparts. Despite the abundant research of the role that parents and schools can play in the prevention of obesity in children, the use of resistance training for altering body composition in this population is a fairly new concept that requires further study (1,9).

It is well established that resistance exercise can be safely undertaken by younger populations (6,7,8,10), but there have been relatively few studies with children who are obese (2,16–18,23). A study by Sothern et al. (16) examining the inclusion of a moderate-intensity, progressive resistance training program for 10 weeks and again at 1 year follow-up for 15 preadolescent obese children (ages 7–12 years) has

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reported the health benefits of preadolescent resistance training as similar to those of adults. A study by Yu et al. (23) has shown that only 6 weeks of resistance training, along with dietary control, improved lean body mass in 41 obese children. Recent studies by Benson et al. (2) and McGuigan et al. (14) have shown that 8 weeks of resistance training can significantly decrease adiposity in obese and overweight children. Because of the growing popularity of youth resistance training and the increasing incidence of childhood overweight and obesity, further long-term studies are needed to evaluate the effects of resistance training on other health and performance measures in obese children, in particular the duration of intervention required to elicit change. It is also of interest to know whether these training-induced benefits can be maintained during a detraining period in this population, because there are limited data in children (19).

Therefore, the main purpose of this study was to assess the effects of resistance training with preadolescent children who were overweight or obese. First, by assessing the different dose responses to resistance exercise, we were able to identify the length of time required to significantly change body composition. Second, we wanted to determine how well these changes in body composition and power measures were maintained when the children discontinued training. It was hypothesized that there would be a significant reduction in the body weight of preadolescent children who were overweight or obese, with the majority of the loss coming from fat as opposed to fat-free mass. Furthermore, it was hypothesized that some improvements in strength, power, and body composition in the children would occur after 8 weeks of training.

Methods

Experimental Approach to the Problem

This study was designed to investigate the effects of 8, 16, or 24 weeks of resistance training on children who are overweight and obese, and the extent to which the benefits are retained after ceasing the structured exercise programs. Children with a body mass index (BMI) ≥ 95th percentile were classified as obese, and those with a BMI ≥ 85th percentile were classified as overweight (11). All subjects were randomly assigned to 1 of 3 training groups and were resistance trained 3 times a week (45–60 minutes per session) under supervision. Group 8 (G8) trained for 8 weeks, group 16 (G16) trained for 16 weeks, and group 24 (G24) trained for 24 weeks. The effect of the training program was evaluated by testing measures of body composition, strength, power, and muscular endurance at weeks 0, 8, 16, and 24 for all groups. In the pretraining testing period, participants initially visited the laboratory to be familiarized with and practice all testing procedures; they also had their measures of body composition and power taken at that time. An initial information session was given to the children and legal guardians. Then, we conducted 2 familiarization sessions that involved the children learning the exercises (typically 1–2 sets of each with low or no resistance) of no more than 10 repetitions. All testing was conducted after these sessions had been completed and before the training intervention proper began.

Subjects

Fifty primary-school-age children with BMIs above the 85th percentile for age were initially recruited into the study. This criterion was based on our previous study (14), where we saw a moderate effect size change for percent body fat of 0.61 (difference between groups of 2.6%) during 8 weeks. Given the higher dosage of resistance exercise in this study (24 weeks), it was estimated that 15 subjects would be needed for each group. However, 19 of these children did not complete the study and withdrew because of time commitments and reasons unrelated to the research study. Therefore, 31 children actually completed the study. Subjects were assigned to 1 of 3 groups, and the resulting group sizes were 6 (4 boys, 2 girls) in G8, 9 (3 boys, 6 girls) in G16, and 16 (8 boys, 8 girls) in G24. Participants ranged in age from 7 to 12 years. Sexual development was reported by the subjects (with the help of their parents) using the Tanner stages of puberty (2,21). Twenty-three children were stage 1, and 8 children were stage 2. The study received ethics approval from the university human subjects research committee. All children and their legal guardians were informed of the experimental risks and were required to sign an informed consent document. In addition, they provided all relevant medical history before the commencement of the study.

Training Program

The resistance training sessions consisted of total body workouts comprising a combination of different body weight and power exercises using a variety of equipment. The program has been previously described and was run as an after-school program (14). The aim was to incorporate exercises that required minimal equipment including dumbbells, elastic bands, medicine balls, and weighted bags. The program consisted of varying training loads within each week of training (i.e., undulating variation) as well as increasing intensity during the 8, 16, or 24 weeks. This type of program has been found to be effective for improving body composition in normal-weight boys (21) and children who are overweight or obese (14).

The first workout consisted of 3 sets of 6- to 8-repetition maximums (RM) during weeks 1–8, 4–6RM during weeks 9–16, and 3–5RM during weeks 17–24. Exercises included squats, bench press, lunges, rows, shoulder press, push-ups, and sit-ups. The second workout involved high-volume, moderate-intensity training sessions. Three sets each of squats, straight-leg deadlifts, flys, front raises, triceps extensions, bicep curls, and heel raises were performed using 12RM, 10RM, and 8RM training loads during weeks 1–8, 9–16, and 17–24, respectively. The third workout involved

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TABLE 1. Subject physical characteristics (mean ± *SD*) for height, weight, and body mass index (BMI) at baseline.

Group	Age (y)	Height (m)	Weight (kg)	BMI (kg·m^{-2})
G8 ($n = 6$)	8.4 ± 4.0	1.3 ± 0.6	55.7 ± 6.2	24.8 ± 2.7
G16 ($n = 9$)	9.8 ± 1.3	1.5 ± 0.1	56.2 ± 13.3	25.3 ± 4.0
G24 ($n = 16$)	9.7 ± 1.4	1.5 ± 0.1	52.3 ± 15.6	24.7 ± 6.8

The G8 group trained for 8 weeks, G16 trained for 16 weeks, and G24 trained for 24 weeks.

moderate- to high-intensity training sessions including explosive power exercises. Three sets each of repetitive body-weight squat jumps, countermovement jumps, explosive hang pulls, bench press, row, shoulder press, and leg curl were performed using 3- to 5-repetition training loads.

Each session was supervised by qualified instructors who kept detailed training logs of all the sets, repetitions, and exercises performed by each subject, and they were later used to measure the overall training compliance. The instructor:-subject ratio for all training sessions was no more than 1:3. Measures of the children's ratings of perceived exertion (RPE) were also recorded after each exercise and at the end of each training session as a monitoring tool. The OMNI RPE scale was used because this scale has been previously validated in children (15).

Nutrient Intake

Nutritional intake was assessed for 3 days (2 "normal" school days and 1 "other/weekend" entry) during weeks 0, 8, 16, and 24 of the study. The children and their parents were provided with specific verbal and written instructions and procedures for recording all foods/beverages consumed during the 3-day period. Dietary records were checked for any significant changes in consumption and eating habits over the course of the study.

Activity Records

Subjects were required to record any significant physical activity that they performed during any 3 days of their choice at baseline. They were asked to include specific information regarding the type of exercise, duration, and intensity (use the RPE rating scale) to rate how hard the exercise was. Activity records were checked for any significant changes in activity levels during weeks 8, 16, and 24.

Anthropometric Measurements

Anthropometric measurements of height and weight were determined using standard procedures at weeks 0, 8, 16, and 24. Body mass was measured on an electronic scale (HW200, A&D Mercury Pty Ltd, Thebarton, Australia) to the nearest 100 g, and height was determined with a wall-mounted stadiometer (Model 220, SECA, Hamburg, Germany) to the nearest millimeter, with children wearing light clothing and without shoes. All anthropometric measures were carried out by the same investigator.

Body Composition and Bone Density

Body composition analyses were made using dual-energy X-ray absorptiometry (DEXA; Discovery-A, Hologic Inc., Bedford, Mass). Each child was asked to remain motionless in the supine position for approximately 5 minutes while the scanning arm of the DEXA passed over his or her body from head to toe in parallel 1-cm strips. Percent body fat from the DEXA testing was subsequently calculated as fat tissue mass divided by the total soft-tissue mass plus the estimated bone mineral content (BMC). Regional analyses of the trunk, arm, and leg regions were also automatically calculated according to anatomic landmarks by the computer software. Coefficients of variation (CVs) in our laboratory (duplicate scans with reposition) for body composition components are

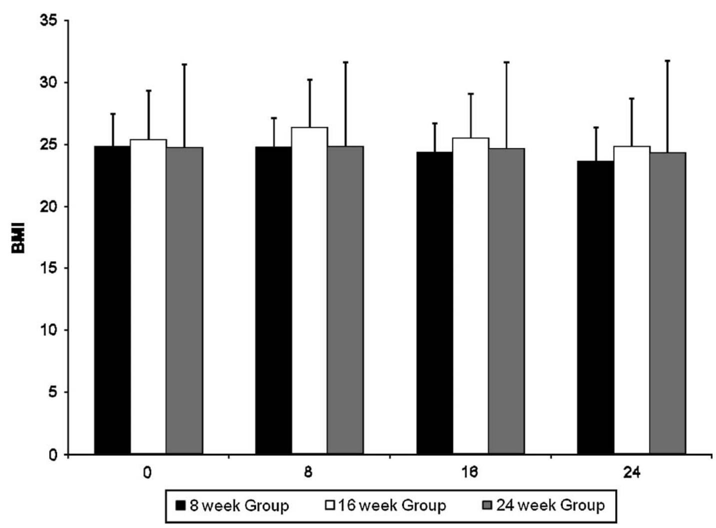

Figure 1. Changes in body mass index (BMI; kg·m^{-2}) for G8 ($n = 6$), G16 ($n = 9$), and G24 ($n = 16$).

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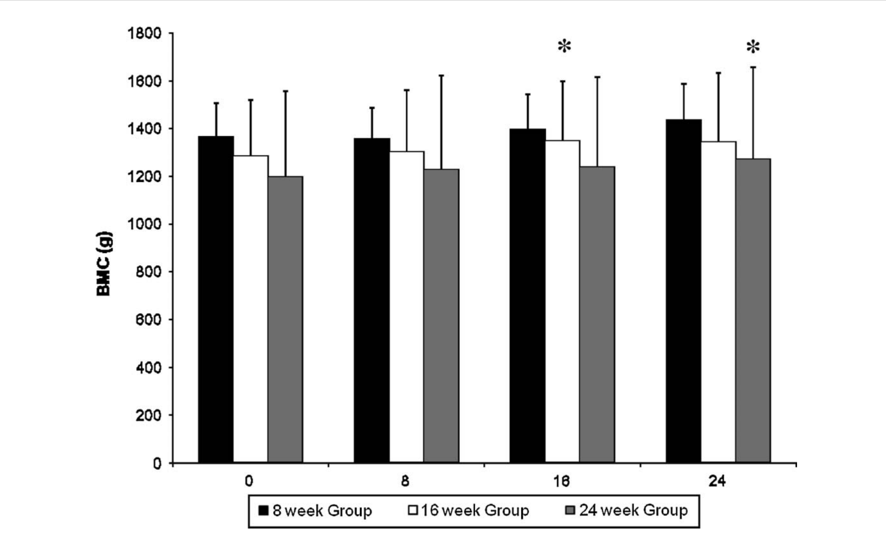

Figure 2. Changes in bone mineral content (BMC; g) for G8 ($n = 6$), G16 ($n = 9$), and G24 ($n = 16$). * Significant change ($p < 0.05$) from baseline.

less than 1.0%, and intraclass correlation coefficients (ICCs) = 0.96 (12).

Power

Power and vertical jump height were measured using the Ballistic Measurement System (Fitness Technology, Adelaide, Australia). Static jump (SJ) squats were performed. During the SJ, each child was asked to pause for 3 seconds at the bottom position before explosively jumping upward. Vertical ground reaction forces were recorded using a force plate (Fitness Technology). Standard biomechanical analyses were performed with the Ballistic Measurement System using the force and displacement measurements. Measures of relative peak power and vertical jump height were recorded. Each subject performed 3 trials, and the best result was used for analysis. The reliability of the test was high, with CV = 5.1% and ICC = 0.96 for power and CV = 9.8% and ICC = 0.96 for jump height (14).

Statistical Analyses

Data are reported as mean ± *SD*. Two-way repeated-measures ANOVA (training group by time) were carried out to determine significant differences between and within groups. An alpha level ≤ 0.05 was used as the criterion to determine significance. Tukey post hoc tests were used to determine where differences existed.

Results

There were no reported training injuries or excessive muscle soreness during the training program. Training compliance was 83 ± 36, 89 ± 12, and 89 ± 7% (mean ± *SD*) for G8, G16, and G24, respectively. Subjects' physical characteristics for height, weight, and BMI at baseline for G8, G16, and G24 are shown in Table 1.

Body Composition Measures

The BMI values of each group over time are presented in Figure 1. No significant group-by-time or within-group interactions were detected. Changes in BMC over time are shown in Figure 2. No significant group-by-time interactions were detected. Pairwise comparisons showed that G16 and G24 both had significant increases in BMC. The G16 subjects showed a 4.9% significant increase at 16 weeks ($p = 0.001$)

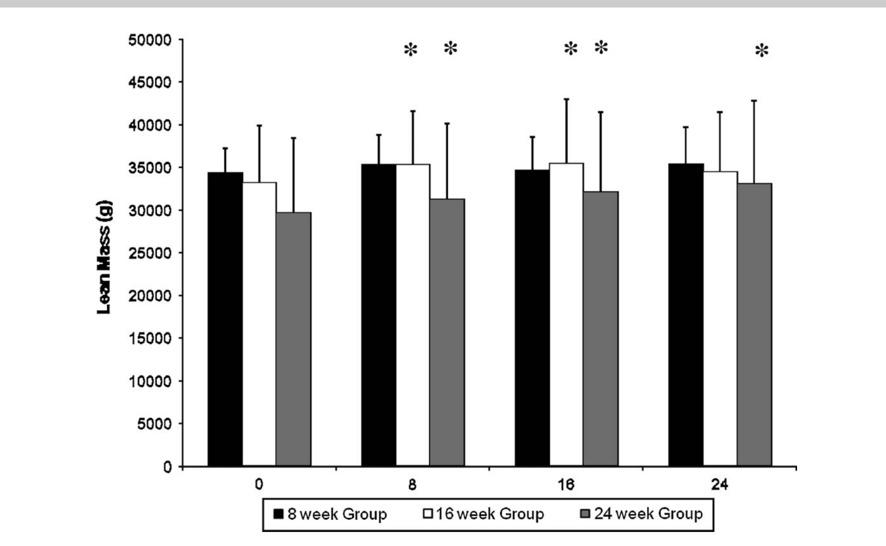

Figure 3. Changes in lean mass (g) for G8 ($n = 6$), G16 ($n = 9$), and G24 ($n = 16$). *Significant change ($p < 0.05$) from baseline.

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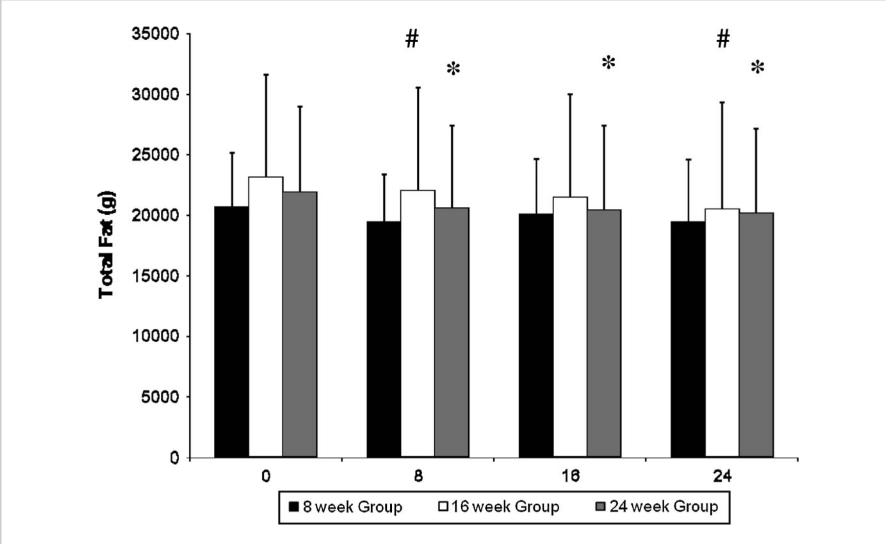

Figure 4. Changes in total fat (g) for G8 ($n = 6$), G16 ($n = 9$), and G24 ($n = 16$). *Significant change ($p < 0.05$) from baseline; #significant group-by-time interaction.

compared with baseline values. The G24 subjects showed a 6.2% significant improvement at week 24 ($p = 0.004$) when compared with baseline values, with no changes observed in G8.

Changes in lean mass for each group are presented in Figure 3. Pairwise comparisons showed that significant improvements in lean mass occurred at weeks 8, 16, and 24 for G16 and G24. The G16 subjects showed a 6.4% increase in lean mass at 8 weeks ($p < 0.001$) and a 6.8% increase at 16 weeks ($p = 0.002$) compared with baseline values. The G24 subjects displayed significant changes at 8, 16, and 24 weeks ($p < 0.001$), where increases in lean mass were 5.3, 8.3, and 11.5% higher (respectively) compared with baseline values. No significant group-by-time interactions were detected.

The effects of training on each group's total fat mass are shown in Figure 4. Significant group-by-time interactions were identified ($p = 0.017$) for changes in fat mass. Baseline values started at 20656 ± 4517, 23117 ± 8498, and 21914 ± 7089 g for G8, G16, and G24, respectively. The G24 subjects displayed significant differences at 8, 16, and 24 weeks ($p < 0.001$), where total fat mass decreased by 5.9, 6.8, and 8.1%, respectively, compared with baseline values.

Changes in percent body fat over time are shown in Figure 5. A significant group-by-time interaction was detected for the changes in percent fat ($p = 0.002$). The G8 and G16 subjects showed significant changes at week 8 ($p = 0.021$ and 0.012, respectively), where percent body fat decreased by 5.3 and 7.0%, respectively. The G24 subjects also showed significant improvements at week 8 ($p < 0.001$), with a 6.7% decrease in percent fat compared with baseline values. These decreases seen by G24 were maintained at weeks 16 and 24.

Changes in SJ power over time are shown in Figure 6. A significant group-by-time interaction was present for SJ power ($p = 0.01$). Pairwise comparisons showed that G24 had significant improvements of 10.5% in SJ power at week 16 ($p = 0.026$).

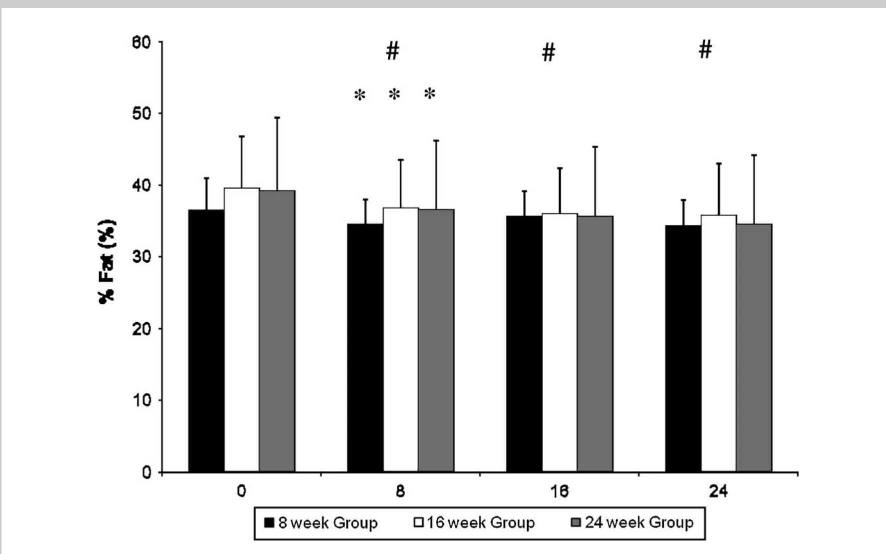

Figure 5. Changes in percent fat for G8 ($n = 6$), G16 ($n = 9$), and G24 ($n = 16$). *Significant change ($p < 0.05$) from baseline; #significant group-by-time interactions.

Nutritional Intake and Activity Levels

No significant changes of nutritional intake or activity levels outside of the extra participation

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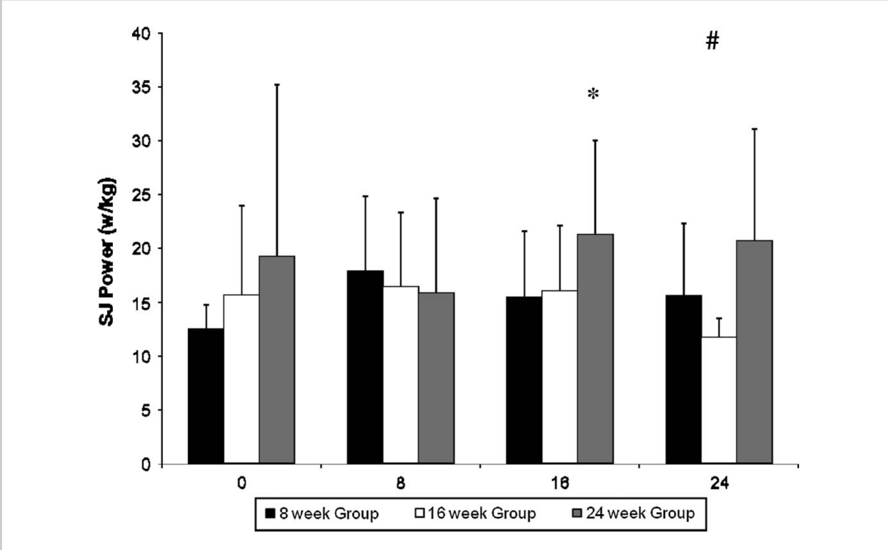

Figure 6. Changes in SJ power (W·kg^{-1}) for G8 ($n = 6$), G16 ($n = 9$), and G24 ($n = 16$). *Significant change ($p <$ 0.05) from baseline; #significant group-by-time interaction.

in the resistance training program were seen over the course of the study.

Discussion

This study investigated the effects of 3 durations of a resistance training intervention on body composition, strength, and power in children who were overweight or obese. Our previous investigation with children who were overweight or obese showed that 8 weeks of resistance training significantly reduced body fat levels (14), and similar findings were made by Benson and colleagues (2). In this study, we were interested in the time course of changes, in whether varying durations of resistance exercise resulted in differential effects, and in how well those changes would be maintained when training was ceased. The most significant group-by-time changes in body composition were seen by the decreases in percentage body fat and total fat mass. The largest improvements were seen in the children who exercised for the full 24 weeks. However, significant improvements in body composition were observed in the initial 8-week training phase. Significant improvements in the power measures were seen by the increases in SJ power. A limitation of the current investigation is the lack of a control group and its relatively low subject numbers. The observed changes cannot necessarily be distinguished from growth and maturation during the study period, but these results do suggest that the resistance training program was able to produce significant and sustainable changes in body composition and power measures. A unique aspect of this study is that we used an undulating periodized program that incorporated power exercises to elicit changes in body composition, strength, and power in children who were obese or overweight.

The most significant group-by-time interactions for body composition were for the changes in percent body fat. Improvements in percent fat (decreases up to 8%) were observed at every testing interval (weeks 8, 16, and 24) for all 3 training groups (G8, G16, and G24). Because such favorable changes were achieved during the initial stages (by 8 weeks) of the resistance training intervention, this indicates that an 8-week resistance training program is sufficient time to produce significant improvements in percent fat in overweight children, supporting the findings from our previous training study (14). Sothern et al. (16) showed that in their moderate-intensity, progressive resistance training program for 15 preadolescent children (ages 7–12 years), significant decreases in percent body fat and weight were seen at 10 weeks. The subjects in the study performed a home-based exercise program that included aerobic, strength, and flexibility exercises (16). Although the aerobic exercise intensity was defined a "moderate," only limited information regarding resistance training intensity was provided. It is important to note that the subjects' dietary intake was not controlled in the present study, and therefore it is difficult to infer how diet affected the overall body composition results, but our analysis indicated that the children did not alter their intake during the course of the intervention.

The results also show that these changes in percent fat can be well maintained. This was shown by the continued decreases in percent body fat from all training groups at weeks 16 and 24. In particular, G8 continued to maintain decreases in percent body fat, even after the cessation of the training program (at weeks 16 and 24). This is in line with Sothern et al. (16), who also observed that percent fat did not increase significantly at their 1-year follow up. Such rapid and sustainable improvements indicate that the study's resistance training program was very effective in decreasing percent fat in obese children.

Yu et al. (23) compared the changes in body composition in 82 school-age overweight/obese prepubertal children who participated in a diet-controlled resistance training program for 6 weeks. They report similar decreases in percent body fat at week 6, suggesting that it may not even take an 8-week training program to produce these results. It should be noted that their subjects performed 75 minutes of activity, which

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included strength (30 minutes), agility (10 minutes), and aerobic training (10 minutes) (plus warm-up and cool-down). Interestingly, they report findings that conflict with those of the present study regarding the effects of continued training on percent body fat. A possible reason for their subjects not sustaining significant decreases in percent body fat, despite the continuation of training, could be the insufficient energy being expended during the exercise bouts and the low frequency of training during the next 26-week phase of their training program (only 1 session per week). This difference could be attributable to the different types of training exercises, durations, and loads used throughout the programs. In our study, significant changes in total fat mass (up to 15% decrease) were observed at weeks 16 and 24 in G16 and G24. However, it was G24 that displayed the most consistent and largest decreases in fat mass throughout the study. This suggests that a 24-week resistance training program would be best suited to elicit and sustain favorable changes in total fat mass in children who are overweight.

Significant changes in lean body mass were observed during the course of the training program at weeks 16 and 24. However, a significant group-by-time interaction was not found. There were no significant changes for any group at week 8, indicating that more than 8 weeks of resistance training are needed to elicit any substantial improvements in lean mass. Interestingly, Yu et al. (23) report significant improvements in lean body mass in their 6-week training group (diet controlled and training) compared with their control group (dietary controlled only). They noticed that improvements in lean mass were maintained (at 36 weeks) by their training group, which is similar to the findings of improved lean mass seen in the present study (observed at 24 weeks) by G24 attributable to continued training. Watts et al. (22) have compared several well-designed and controlled studies that evaluated the effects of exercise training in children and adolescents who were obese on body composition and muscular strength. Their interpretation of the findings was that because resistance training can cause increases in lean body mass and, possibly, enhance fat loss in adults, it could be inferred that similar trends might be seen in children. Trends of improved lean body mass with continued resistance training were identified in the present study's population, even though statistical significance was not achieved.

No significant group-by-time interactions were observed for changes in BMI between any of the groups during the course of this study. The most likely explanation for this is that significant increases in lean body mass were observed in G16 and G24, because this would alter body composition and negatively affect BMI. Whereas other studies have shown the efficacy of using BMI (11,23), it has to be questioned whether this is the most accurate method of measuring obesity in children. Measurement of BMI alone does have limitations for assessing overweight/obesity, and it is suggested that other measures of assessing body composition in children, such as skinfolds or DEXA, should be considered (22). In the present study, BMI was used to categorize subjects as overweight or obese for inclusion in the study. Among adults, BMI is highly correlated with adiposity (as assessed by methods such as DEXA) (11). Associations among children have been more variable, and associations are relatively weak in some subgroups (11).

Hussey et al. (13) have suggested that the use of BMI in children as the sole identifier may substantially underestimate the incidence of overweight. They argue that BMI does not effectively reflect changes in body composition, because 31% of their subjects had BMIs above the 75th percentile, and 76% had waist circumferences above the 75th percentile. It is therefore hypothesized that percent body fat measures give a more accurate indication of changes in body composition in children as opposed to BMI. This is supported in the present study, where BMI baseline values ranged from 20.5 to 32.8, whereas percent body fat baseline values ranged from 25.3 to 46.3%. In the present study, we found a moderate correlation between BMI and body fat percentage ($r = 0.61$). However, Sothern et al. (16) have noted a significant decrease in BMI in their 10-week, moderate-intensity, progressive resistance training program for preadolescent children who were obese, and they report that BMI did not increase significantly at 1-year follow up. It can be inferred that percent body fat measures will give the better indication of body composition comparisons, especially in children.

Similarly, no significant changes over time were observed for BMC between any of the training groups. This could be attributable to several factors. First, it is possible that 24 weeks may be an insufficient period of time to elicit any significant changes in BMC in this population. Second, the amount of loading and intensity of the training sessions used in this study may have been insufficient to increase bone density. Volek and colleagues (21) examined the effects of increasing milk on bone and body composition responses to high-intensity resistance training in a 12-week program for 28 adolescent boys and observed significant increases in both BMC and bone mineral density in response to a much shorter resistance training program but using higher loading than the present study.

Increases in SJ power were significantly increased at week 24 for G24. Interestingly, there were no changes observed for any group at weeks 8 or 16; however, by week 24, all 3 training groups showed significant improvements in SJ power. This would suggest that 24 weeks is a more realistic time frame to elicit positive changes in SJ power in children. It must also be noted that G8 and G24 displayed very large variations in SJ power across the entire study. The notion of responders vs. nonresponders between and within subject groups is the most likely reason for the variation seen in our strength and power measures. Further investigation into the optimal load and intensity for a resistance training program in children who are overweight or obese is necessary. The lack of a control group does mean that is difficult to clearly distinguish the resulting

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changes from growth and maturation during the study period. However, the results do suggest that the resistance training program was tolerated well by the participants and was able to produce significant and sustainable changes in body composition and power.

Practical Applications

This study supports the participation of children who are overweight or obese in a resistance training exercise program because significant improvements in percent body fat, total fat mass, and SJ power were observed over time. Further, many of these improvements seem to be well maintained for a subsequent 8- to 16-week period post the initial intervention. It does seem that, for most measures, the improvements could be seen quite rapidly at the commencement of a training program and that they can be well maintained for some time, even after training has finished. A periodized training program incorporating power exercises seems to provide an effective stimulus for children who are overweight or obese in terms of changing body composition and improving physical capacities such as strength and power. Strength and conditioning specialists can contribute to reducing the problem of childhood overweight and obesity because they have the greatest understanding and skills for implementing periodized resistance training programs. Appropriate program design and equipment such as dumbbells, weighted bags, and bands can be used effectively to improve body composition and strength and power in children who are overweight or obese.

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