Exercise Adherence and Intervention Effects of Two School-Based Resistance Training Programs for Adolescents

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Abstract

Objective: The aim of this study was to evaluate the efficacy and feasibility of two school-based RT programs to improve muscular fitness and body composition in adolescents.

Methods: The study was conducted in Australia from July 2008 to June 2009. Participants [*n* = 108, mean age (SD) = 15.0 (0.7) years] were randomized to free weights (*n* = 37) or elastic tubing (*n*= 41) RT groups and a control group was recruited (*n* = 30). Participants in the RT groups completed 2 sets of 10-12 repetitions on 10 exercises for 8 weeks. Waist circumference, body composition (bio-impedance analysis) and muscular strength (bench press and leg press) were assessed at baseline and posttest.

Results: Boys ($p< 0.001$) and girls ($p< 0.01$) in both RT groups improved their body composition over the study period. Boys in both RT groups significantly improved both upper and lower body strength and their improvements were significantly greater than changes observed in the control group. Girls in the free weights groups achieved larger improvements in lower body strength compared to the control group ($p< 0.05$).

Conclusions: Free weights and elastic tubing RT are feasible and effective strategies for improving aspects of health-related fitness in adolescents.

Key words: Physical activity; secondary school; obesity, muscular fitness; exercise; physical fitness; strength training; weight training

Introduction

Due to the benefits of physical activity and concerns regarding obesity prevalence, the promotion of physical activity among youth has emerged as a global health priority (Pushka, et al., 2003). While physical activity opportunities for children should focus on developing fundamental movement skills (Gallahue and Ozmun, 2006), this focus should shift towards health-related fitness and lifetime activities in adolescence (Strong, et al., 2005). Lifetime activities generally only involve one or two people and require little organization (e.g. swimming, tennis, aerobics and resistance training). Individuals who develop a routine of participating in lifetime activities that can be easily carried into adulthood may be more likely to become active adults (Corbin, 2002).

Resistance training (RT) is a lifetime activity designed specifically to increase muscular strength and endurance through increased workload demand on muscles. Historically, RT has not been recommended for children and adolescents due to the perceived threat of injury and the belief that it could stunt linear growth (Faigenbaum, 2000). While the majority of previous studies have focused on prepubertal children, supervised RT programs do not appear to have any adverse effects in youth (Malina, 2006). Conversely, studies have found that RT has many benefits for adolescents, including increased muscular fitness (Benson, et al., 2008a, Shaibi, et al., 2006), decreased body fat (Benson, et al., 2008a, Shaibi, et al., 2006) and improved blood lipid profiles (Benson, et al., 2008a, Lau, et al., 2004). However, determining the specific effects of RT in healthy adolescents is difficult because previous studies have failed to include a control group (Faigenbaum, et al., 2007), focused on obese adolescents (Lau, et al., 2004, Shaibi, et al., 2006, Watts, et al., 2004), combined prepubertal children and adolescents in the same sample (Benson, et al., 2008a, Stahle, et al., 1995) and failed to separate results by gender (Benson, et al., 2008a, Watts, et al., 2004). Overweight youth are more likely to show favorable changes in body composition in response to RT compared to healthy weight adolescents and changes in strength in children may be difficult to distinguish from growth and maturation (Faigenbaum, 2000).

The prevalence of pediatric obesity (Hossain, et al., 2007) and the increasing burden of sarcopenic obesity (i.e. increased body fat and reduced lean mass) among adult populations (Villareal, et al., 2005) emphasize the importance of engaging individuals in RT to improve body composition and muscular fitness from an early age. While RT with free weights is known to improve health-related and metabolic fitness in adolescents (Benson, et al., 2008b, Faigenbaum, 2000), less is known regarding the feasibility and efficacy of elastic tubing/stretch bands in youth. Elastic tubing/stretch bands have typically been used for rehabilitative purposes (Damush and Damush, 1999, Krebs, et al., 1998) rather than for fitness training, although there is some evidence to suggest that training programs involving elastic bands or tubing increase muscle strength in adults (Mikesky, et al., 1994, Page, et al., 1993). The aim of this study was to evaluate the efficacy and feasibility of two school-based RT programs to improve muscular fitness and body composition in adolescents.

Method

Study population and design

Approval for the study was obtained from the University of Newcastle Research Ethics Committee and the school principal from one non-government secondary school in Newcastle, New South Wales (NSW), Australia and all participants provided informed consent. The flow of participants through the study process is reported in Figure 1. Eligible participants were untrained secondary school students at the study school in years 9 to 10. Participants were ineligible if they were currently doing RT, had extensive experience with RT (i.e. individuals who had completed a formal RT program designed to improve fitness and or sporting performance were not eligible), or if they had a medical condition or physical injury preventing testing or training. Sessions were run separately for year 9 and 10 students and were evaluated from July to December 2008. The study involved two recruitment phases. In the first phase of recruitment, 79 students were recruited and randomized using a computer-based random number-producing algorithm to elastic tubing or free weight resistance training groups. The randomization process was stratified by gender and year group at school to ensure equal numbers in the two treatment arms. Randomization to RT conditions occurred after baseline testing and was conducted by a member of the research team who was not involved in the assessments. In the second stage, a control group was recruited (n = 30) from the study school and were assessed from April to June 2009. Participants in the control group were offered the RT programs following the completion of the study. A power calculation based on change in upper body strength was calculated. Based on a previous study, an increase of 10kg in upper body strength was achievable (Benson, et al., 2008a). Using an alpha of 0.05 and power of 80%, a sample size of 11 per group (elastic tubing, free weights and control) was needed to detect a 9kg difference between groups. Considering study drop-out and to allow for separate gender analyses, a sample size of approximately 100 students was needed (33 students in each study arm).

Treatment conditions

The control group was asked to refrain from any resistance training and maintain their normal physical activity and nutrition behaviors. The free weights and elastic tubing groups participated in progressive RT programs delivered during lunch-time twice a week for 8-weeks. Due to physical education curricular restrictions, the RT programs were offered as lunchtime activities and participants were advised to eat their lunch at the completion of the RT session. Instructors were university educated physical education teachers and the instructor to participant ratio was 1:15. Before commencing each session, participants completed 5 minutes of aerobic activity (cycle or other ergometer) and dynamic stretching (i.e. leg swings, body weights squats). In each session, participants completed 2 sets of 8-12 repetitions (10-12 repetitions in weeks 1-4 and 8-10 repetitions in weeks 5-8) for 10 exercises (session duration 40-50 minutes) with 60-90 seconds rest between sets. Elastic tubing exercises were completed in the following order: squat, lunge, calf raise, bent over row, chest press, front raise, biceps curl, triceps extension, crunch, and Russian twist. The free weights exercises included the following: squat, lunge, calf raise, bent over row, bench press, front raise, biceps curl, triceps extension, crunch, and Russian twist. Participants in the free weights RT group used standard dumbbells, barbells and benches. The elastic tubing RT group used the elastic tubing RT device known as the Gymstick™. The device consists of a graphite shaft that has elastic tubing with foot straps connected to each end of the shaft enabling the trainer to complete a wide range of resistance exercises. Gymsticks™ are available in five different resistance levels and the load on each device can be increased by rolling the bar and shortening the elastic tubing.

Borg's rating of perceived exertion (RPE) was used to determine the training intensity and progression for both RT groups (Borg, 1998). The training intensity involved 8-12 repetition maximum and participants were encouraged to achieve an RPE of 15-18 and reach volitional failure for the last repetition of each set. Previous studies have shown that Borg's scale is readily learned by adolescents (Williams, et al., 1991), and is a valid instrument for monitoring exercise exertion in this age group (Robertson and Noble, 1997). Participants in the RT groups were asked to maintain normal eating and physical activity patterns over the duration of the study. During the study period all participants completed their usual PE and school sport programs which consisted of 120 minutes of school-based physical activity each week.

Measures

All assessments were completed by trained research assistants and measurements were completed at the study school. The primary outcome was muscular strength and the secondary outcome was body composition. *i) Muscular strength:* Maximal muscular strength was assessed using a progressive repetition maximal lift (1RM) protocol, which includes two phases and has good test-retest reliability (*r*=0.93) (Benson, et al., 2008a, Faigenbaum, et al., 1988). In the familiarization phase, the instructors demonstrated the lift and then the participants were instructed on correct form and breathing and given 2-3 practice lifts with a light bar or no weights. In the testing phase, the weights were increased until the subject can no longer lift the weight, despite verbal encouragement on two consecutive attempts 90 seconds apart. Upper body strength was assessed using a supine bench press and lower body strength was determined using an incline seated leg press. *(ii) Height and weight:* Weight was measured in light clothing without shoes using a portable digital scale (Seca 770, Wedderburn) to the nearest 0.1kg and height was measured to the nearest 0.1 cm using a portable stadiometer (PEb7). Body mass index (BMI) was calculated using the standard equation (weight[kg]/height[m]^2) and age-specific cut-off points from the International Obesity Task Force were used to classify participants as healthy weight, overweight or obese (Cole, et al., 2000). *(iii) Waist circumference:* Non-extensible steel tapes (KDSW-2008) were used to assess waist circumference, which was measured level with the umbilicus to standardize the procedure. *(iv) Body composition*: Percentage body fat, fat mass (FM) and fat free mass (FFM) were determined using the Imp™ SFB7 bioelectrical impedance (BIA) analyzer (Moon, et al., 2008, Scharfetter, et al., 2005). The Imp™ SFB7 is a multi-frequency, tetra polar bioimpedance spectroscopy (BIS) device (Nielsen, et al., 2007). Participants were asked to refrain from physical activity before testing and to maintain normal hydration patterns.

Process evaluation

A detailed process evaluation was undertaken to assess the feasibility of the school-based RT programs. The following data were collected: *(i) Session attendance*- attendance at all sessions was recorded and compliance indices were calculated by dividing the total number of sessions attended by the total number of sessions prescribed. *(ii) Program adherence*- intensity adherence was determined by dividing the average RPE for every set completed. *(iii) Adverse events and injuries*- research assistants and instructors were asked to record any injuries or adverse events that occurred at assessments or during the program sessions. *(iv) Program satisfaction*- at the completion of the study, participants were asked to rate their overall satisfaction with their RT program using a 3-item scale developed for the study. Cronbach alpha α=0.77 and possible scores ranged from 3 to 15.

Statistical Analyses

Data analysis was undertaken using the Statistical Package for the Social Sciences (SPSS, version 16, SPSS Inc., Chicago, Ill, USA). Differences between groups at baseline and characteristics of completers versus dropouts were tested using one way analysis of variance (ANOVA) and independent samples t-tests, respectively. Repeated measures ANOVA were used to identify group-by-time interaction effects for participants who completed the study with age included as a covariate. Where significant interaction effects were found, change scores (posttest minus baseline) were compared using one way ANOVA with a Bonferroni post hoc procedure and effect sizes (d=M_1 - M_2 / σ_{pooled}) were calculated. Effect sizes were defined as small (d=0.2), medium (d=0.5) and large (d=0.8) (Cohen, 1988). Chi-square (χ^2) was used to compare drop-out rates for free weights and elastic tubing RT groups. All data are presented as mean and standard deviation (± SD).

Results

Participants

The average age of participants was 15.0 (±0.7) years. Most participants spoke English as their first language and were born in Australia (Table 1). Nineteen participants (18% of study sample) were overweight or obese (6 in the control group, 7 in the free weights RT group and 5 in the elastic tubing RT group). At baseline, boys in the control group achieved significantly more upper bench strength (p<0.05) than those in the RT groups. Girls in the free weights group were significantly heavier than girls in the control group (p<0.05). There were no significant differences between completers and drop-outs for any of the outcome variables.

Body composition

The results for participants who completed both baseline and posttest assessments are reported in Table 2 (boys) and Table 3 (girls). There were no significant group-by-time interaction effects for waist circumference for boys or girls. Boys in both RT groups reduced their fat mass and increased their fat free mass resulting in a significant group-by-time interaction effect for % body fat (p<0.01) (Figure 1). Post hoc analyses indicated that both RT groups had significantly decreased their body fat in comparison to the control group. Similarly, girls in both RT groups improved their body composition over the study period and significant group-by-time interaction effects were found for body mass index (BMI)($p<0.01$) and % body fat ($p<0.01$). Post hoc analyses indicated no significant differences between girls in the RT groups. However, effect sizes for the free weights RT group were larger than those observed in the elastic tubing RT group for both boys and girls. The effects of the RT programs on body composition (% body fat) were similar for those identified as overweight/obese at baseline [free weights RT (baseline 28.5% to posttest 27%) and elastic tubing RT (baseline 24.7% to posttest 22.3%)] to healthy weight individuals [free weights RT (baseline 18.9% to posttest 16.6%) and elastic tubing RT (baseline 18.7% to posttest 17.9%)].

Muscular strength

Boys in both RT groups significantly improved upper ($p<0.01$) and lower body strength ($p<0.05$) over the study period and their improvements were significantly greater than changes observed in the control group. Effect sizes for improvements in upper body strength were larger in the free weights RT group (24% increase, $d=1.2$) compared to the elastic tubing RT group (12% increase, $d=0.6$). Increases in lower body strength were similar for boys in both groups (32% elastic tubing and 35% free weights). Girls in the free weights groups achieved larger improvements in lower body strength in comparison to the elastic tubing and control groups (, $p<0.05$). For girls, effect sizes for absolute lower body strength were $d=1.6$ (32% increase) for the free weights RT group, $d=1.1$ (19% increase) for the elastic tubing RT group and $d=0.5$ for the control group.

Process evaluation

Twelve participants (8 boys and 4 girls) from the free weights RT group dropped out of the study and 25 completed baseline and posttest measures (68%). Boys and girls in the free weights RT group attended 79% and 73% of training sessions, respectively. The average RPE for each set completed was 14.4 (±1.9) for boys and 15.4 (±1.6) for girls. The dropout rate was higher among participants in the free weights RT group, compared to the elastic tubing RT group ($\chi^2=6.08$, $p<0.05$). In the elastic tubing RT group, 32 participants completed the study (78%), eight participants dropped out of the study (5 boys and 3 girls) and one was not available for testing due to illness. Boys and girls in the elastic tubing RT group attended 78% and 79% of training sessions, respectively. The average RPE for each set completed was 14.7 (±2.1) for boys and 13.4 (±1.4) for girls. No injuries or adverse effects were reported during training sessions or assessments. At the completion of the study, participants in both the free weights

(11.3±2.4) and the elastic tubing (11.6±1.8) RT groups reported relatively high satisfaction with their respective RT programs.

Discussion

The aim of this study was to evaluate the efficacy and feasibility of two school-based RT programs to improve muscular fitness and body composition in adolescents. The major findings of this study are that both boys and girls who completed 8-weeks of elastic tubing and free weights RT significantly improved their body composition and muscular strength in comparison to a control group. While larger effect sizes were found in the free weights RT group, program adherence was higher and drop-out rate was lower among participants in the elastic tubing RT group.

Interventions to prevent (Flodmark, et al., 2006) and treat obesity (Latzer, et al., 2008) among children and adolescents often result in small and/or non-significant changes in adiposity. However, recent RT studies have been found to significantly improve body composition in overweight/obese adolescents (Benson, et al., 2008a, Shaibi, et al., 2006). In the current study, participants in both RT groups significantly improved their body composition over an 8-week study period. Boys in both RT groups reduced their fat mass and significantly increased their fat free mass. Similarly, girls in both groups reduced their fat mass and significantly improved their BMI. It is interesting to note that decreases in body fat in the current study were accompanied by increases in fat free mass among boys in both RT groups. Evidence from the bioelectrical impedance analysis indicates that increases in lean muscle mass occurred in both RT groups. There were no statistically significant changes in waist circumference among boys or girls among either group over the 8-week study period. In contrast, Benson and colleagues (Benson, et al., 2008a) found a 0.8cm reduction in waist circumference that was statistically significant in their study with children and adolescents after 8-weeks of high intensity RT. It should be noted that 51% of their study sample was overweight or obese at baseline and greater reductions in body fat among these individuals are possible. In comparison, only 18% of the current sample was overweight or obese.

The high drop-out rate of participants in programs to prevent and treat obesity has been identified as an issue of considerable concern (Latzer, et al., 2008). Previous RT studies have reported attendance compliance of >80% (Benson, et al., 2008b), which is comparable to the current study. While this has not been established in adolescents, research with adults indicates that exercise adherence is inversely related to exercise intensity (Perri, et al., 2002). This suggests that as exercise intensity increases, higher rates of drop-out are observed. In the current study, the drop-out rate was higher among participants in the free weights group (68% completed) compared to the elastic tubing group (78% completed) and significantly more participants dropped out of the free weights group. While students reported relatively high satisfaction with their respective RT programs, students attended only attended 75% of sessions. Finding time for additional physical activity within the school day is difficult due to the crowded school curriculum (Biddle, et al., 2004). It is plausible to suggest that participants failed to attend some of the sessions due to additional academic and extra-curricular commitments.

It should be noted that neither program included behavior change strategies to increase exercise adherence. Both programs were delivered at schools during lunch-time and all sessions were voluntary. Unlike previous programs which have focused on obese adolescents (Lau, et al., 2004, Shaibi, et al., 2006) or combined children and adolescents in the one program (Benson, et al., 2008a, Stahle, et al., 1995), the current study involved adolescents only and the program was offered as a non-compulsory lunch time activity. Children are generally more compliant than adolescents and evidence clearly indicates that adolescence is a period associated with a steep decline in physical activity (Nader, et al., 2008). While changes in body composition and muscular fitness may revert to pre-training levels once individuals are no longer training, RT programs combined with behavioral modification strategies (e.g. self-monitoring and goal setting) provide adolescents with knowledge and skills that can be transferred into adulthood to promote lifelong physical activity. Future studies should evaluate the long-term adherence and effects of school-based physical activity interventions incorporating elastic tubing RT with goal setting principles and strategies to enhance social support.

Girls and boys in both RT groups significantly increased their muscular strength over the study period and the only statistically significant difference between RT groups was found for lower body strength in girls. However, the increases in strength observed in the elastic tubing RT group were smaller than those observed in the free weights group for both upper (boys 12%, girls 13%) and lower body strength (boys 32%, girls, 19%). Strength increases for boys (upper 24% and lower 35%) and girls (17% and 32%) in the free weights RT group were similar to those identified in a previous study with adolescents (Shaibi, et al., 2006). Shaibi et al (2006) found that obese adolescent males increased their upper and lower body strength by 26% and 28%, respectively, following 16-weeks of RT. Larger increases in upper (39%) and lower (39%) body strength were found in another RT study which included both children and adolescents (Benson, et al., 2008a). It is interesting to note that upper body strength decreased among participants in the control group over the study period. It is unlikely that participants in the control group actually decreased their strength over the study period. While the same testing protocols were utilized with all groups at assessments, participant motivation and measurement error may partially explain this finding. Finally, it should be noted that some of the increases in upper body strength found among boys and girls in the free weights groups may be attributable to testing-training specificity, as bench press was included as one of the exercises in the free weights program.

Boys in the free weights group increased their strength by more than the girls in the free weights group and similar trends were observed in the elastic tubing RT group. The majority of previous studies have focused on children and prepubertal adolescents and studies that have included male and female adolescents have not separated results by gender (Benson, et al., 2008a, Watts, et al., 2004). Consequently, little is known about gender differences in strength training adaptations in healthy adolescents. It is interesting to note that girls in the free weights group achieved similar increases in strength to the boys in the elastic tubing group.

Limitations and strengths

The findings from this study are limited by the following. First, body composition was assessed using bio-impedance analysis. While hydrostatic weighing or dual energy X-ray absorptiometry may provide more reliable estimates of body composition, body fat predictions from tetra-polar bioimpedance have been found to correspond favorably with the latter in youth (Nielsen, et al., 2007). Second, while we asked participants to maintain their normal physical activity and dietary patterns over the study period, we did not require participants to record their behaviors over the study period due to the perceived participant burden this would entail. Third, the familiarization phase of the testing was conducted on the same day as the actual testing. Ideally, practice trials should be completed at least one day prior to the testing to account for training-induced strength gains resulting from the learning effect. Finally, the study was underpowered to detect smaller between group differences. To overcome this limitation, effect sizes have been reported.

This is the first study to evaluate the effects of elastic tubing resistance training in adolescents and our findings have important implications for the promotion of muscular fitness in this age group. Our study involved a strong experimental design and where possible we have adhered to the CONSORT statement.

Conclusions

Recent studies have identified the importance of muscular fitness to the current and future health of young people (Ortega, et al., 2008, Ruiz, et al., 2009, Steene-Johannessen, et al., 2009). Consequently, the current physical activity recommendations for youth include guidelines to improve muscular fitness (U.S. Department of Health & Human Services, 2008). While schools have been recognized as important institutions for the promotion of physical activity among youth (Wechsler, et al., 2000), few studies have examined the efficacy and feasibility of school-based RT programs in adolescents. Furthermore, this is the first study to evaluate the efficacy of elastic tubing RT in adolescents. This study has shown that RT with free weights and elastic tubing devices are feasible and effective approaches to physical activity promotion among adolescents in secondary schools. While the drop-out rate was higher among participants in the free weights RT group, elastic tubing RT has a number of limitations that should be noted. First, training adaptations made in response to elastic tubing RT were smaller than those observed in the free weights group. Second, the elastic tubing devices are ineffective at inducing high loads in a complete range of motion due to the nature of the bands which increase in difficulty with added length. Finally, maintaining an adequate grip position can be difficult for some exercises and there is also the potential for the bands to snap and cause injury.

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Table 1: Baseline characteristics of participants (Australia, July 2008 to June 2009)

Table 2: Changes in primary and secondary outcome measures for girls who completed the study (Australia, July 2008 to June 2009)

Table 3: Changes in primary and secondary outcome measures for boys who completed the study (Australia, July 2008 to June 2009)

Figure 1: Flow of participants through the research process (Australia, July 2008 to June 2009)

Figure 2: Intervention effects on muscular strength and body composition (Australia, July 2008 to June 2009)