NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH Public Access
Author Manuscript
J Strength Cond Res. Author manuscript; available in PMC 2010 November 1.

Published in final edited form as:
J Strength Cond Res. 2009 November ; 23(8): 2287–2294. doi:10.1519/JSC.0b013e3181b8d42a.

The Effects of Manual Resistance Training on Fitness in Adolescents

Sandor Dorgo[1], **George A. King**[1], **Norma Candelaria**[1], **Julia O. Bader**[2], **Gregory D. Brickey**[1], and **Carolyn E. Adams**[3]

[1]Department of Kinesiology, The University of Texas at El Paso

[2]Department of Mathematical Sciences, The University of Texas at El Paso

[3]School of Nursing, The University of Texas at El Paso

Abstract

Manual Resistance Training (MRT), an alternative to traditional resistance training, requires minimal equipment and may be effective when applied in school-based physical education (PE) classes. The purpose of this study was to document the physical changes in adolescents (N = 222) using MRT in school-based PE settings. Six fitness tests from the Fitnessgram assessment tool were selected to assess students' cardiovascular and muscular fitness and skin-fold tests were used to assess body composition. One Control and two Experimental Groups were defined. The Control group of students (N = 129) attended regular PE classes. One Experimental group (N = 63) attended PE that was complemented by the MRT system. A second Experiment group (N = 30) attended PE complemented by MRT and cardiovascular endurance training. Using the selected Fitnessgram tests post-test measurements were done after 9 and 18 weeks of PE. At baseline, there were no significant differences between the three groups for most measures. Compared to baseline, experimental groups improved significantly in all six fitness measures and showed more improvements than the Control group in most fitness measures both at 9 and 18 weeks. None of the groups showed significant improvement in body composition. The results documented that an MRT complemented PE program was effective in improving adolescents' muscular fitness. An 18-week combined MRT and cardiovascular endurance training program effectively improved cardiovascular and muscular fitness but was ineffective in improving adolescent body composition. An MRT based exercise session requires minimal equipment and set-up, and can be performed in a short period of time, therefore it is suitable for application in regular PE settings.

Keywords

strength training; youth fitness; adolescent fitness; resistance training modalities; school resistance training

Introduction

The transition from early to late adolescence is associated with decreased levels of physical activity and an increased prevalence of a sedentary lifestyle (2,20). Most adolescents fail to meet the recommended minimal levels of physical activity (2,22) necessary for optimizing physical development and body composition (1), which is a major public health concern

Correspondence: Sandor Dorgo, Department of Kinesiology, The University of Texas at El Paso, 1101 N. Campbell St., El Paso, TX 79902, Phone: (915) 747-7222, Fax: (915) 747-8211, sdorgo@utep.edu.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

(2,5,14). Many children and adolescents are only exposed to vigorous physical activity during school-based physical education classes (3) and the majority of adolescents do not participate in any organized physical activity during non-school hours (2). Therefore, physical education (PE) has a vital role in establishing positive lifestyle behaviors and improving fitness in children and adolescents. It is important to ensure that during PE students are exposed to physical activities that promote physical development and an active lifestyle. In general, PE classes include games, skill development exercises for various sport and leisure activities, and more increasingly, fitness activities. To promote the engagement in life-long physical activity, PE classes must be enjoyable to all children and adolescents, but at the same time must be vigorous enough to address the lack of physical activity outside of school. Resistance training during school PE may help address these issues.

The term resistance training refers to a specific method of physical conditioning that involves the use of a wide range of resistive loads and a variety of training modalities (e.g., free weights, weight machines, elastic cords, medicine balls, and body weight) (10). It is recognized that youth resistance training can be a safe, effective, and beneficial method of conditioning and should be an important component of youth fitness programs, health promotion objectives, and injury prevention (11,13). Resistance training may have multiple physiological benefits for youth (10,11,26), may provide enjoyment and positive attitude toward lifetime physical activity (4,9,10,15,26), and may promote adherence to regular exercise among children and adolescents (10,11).

Traditionally, resistance training (also referred to as weight training) is based on the use of a variety of expensive equipment (i.e. free-weights and exercise machines) (8). While some high schools have well developed facilities adequate for engaging a large number of students in weight training sessions, resistance training is often excluded from PE curricula because of space and budget constraints. As an alternative, the Manual Resistance Training (MRT) system requires minimal equipment because the resistance for an exercise movement is provided by one or more partners and traditional weight training equipment, such as bars, dumbbells, and plates are not used. Most traditional free weight and machine based resistance training exercises can be simulated and appropriate training stimuli provided when MRT exercises are properly designed. To establish an effective training position or exercise set-up for MRT only limited equipment is necessary, which may include benches, chairs, tables, step boxes, PVC pipes and straps. The application of MRT in adults has been shown to result in improved fitness and muscular strength (7,19,27), and improvements may be comparable to those achieved through traditional weight resistance training (8). However, no known data exists for this training method in adolescents. While a limitation of the MRT method is the inability to quantify the applied resistance (8), the advantages of minimal, portable and inexpensive equipment requirements make the MRT system appealing for school-based PE programs. Consequently, it was hypothesized that the MRT system could be applied in PE classes and should improve the physical fitness and body composition of adolescents to a greater extent than traditional physical education activities. Therefore, the purpose of this study was to document the changes in physical fitness scores and body composition measures of adolescents through the application of Manual Resistance Training and cardiovascular endurance training in school-based PE settings compared to adolescents attending a traditional PE program.

Methods

Experimental Approach to the Problem

The independent variable in the experimental design included an 18-week Manual Resistance Training (MRT) intervention applied in high-school-based PE classes. Individual assessments as dependent variables were conducted at baseline (pre-), at 9 weeks

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

(midterm-), and at 18 weeks (post-training) of the intervention and included body mass index (BMI), skinfold thickness, and physical fitness including the one-mile run, curl-up, trunk lift, push-up, flexed-arm hang, and modified pull-up tests. One Control and two Experimental Groups were defined. Adolescents attending PE classes were recruited as subjects and classes were randomly assigned to one of the three program groups: (a) a regular PE program that followed the usual school curriculum (Control); (b) a PE program that utilized the MRT in every class session (MRT); or (c) a PE program that included MRT and a cardiovascular endurance training segment in every class session (MRT+E). The 18-week intervention was implemented during the 22-week academic semester with 1-week allocated for pre-testing, midterm-testing, spring vacation break, and post-testing, respectively.

Subjects

After obtaining permission to conduct the study from all necessary Institutional Review Boards, physical education programs from two public high-schools were selected for the study. A total of 407 high-school students enrolled in PE classes at the selected high-schools were invited as study subjects with the assistance of the physical education teachers and 373 agreed to participate. Students were asked to provide a signed Assent Form and a Parental Informed Consent Form signed by a parent or guardian. The complete testing procedure and training protocol were thoroughly explained to all students both orally and in writing. Exclusion criteria for study participation included cardiovascular problems, spine deformities, and pregnancy. Two physical education teachers at each school cooperated with the researchers and agreed to assign their classes to one of the three program groups. Class sizes at the beginning of the intervention ranged from 30 to 82 students, with an average 1:40 teacher-to-student ratio. Pre-training descriptive characteristics of the subjects are presented in Table 1.

Procedures

Each student's physical attributes were assessed using selected tests from the Fitnessgram assessment tool (19); an assessment tool used widely in schools to measure level of fitness. Selected components of the Fitnessgram included the one-mile run, curl-up, trunk lift, push-up, flexed-arm hang, and modified pull-up tests and BMI calculations. One-mile run performance was defined as the time required for a student to complete the one-mile distance. Curl-up, push-up, and modified pull-up performances were defined as the number of correct repetitions a student was able to perform. Trunk lift was defined as the greatest distance a student was able to lift the chin from the ground in a prone position. Flexed-arm hang was defined as the time a student was able to maintain the flexed-arm hang position from a high-bar with the chin above the bar. Detailed descriptions of these assessment procedures with reported validity and reliability have been published elsewhere (28). In addition to the Fitnessgram tests, skinfold measurements were used to assess percentage of body fat. Skinfold thickness was calculated as the sum of triceps, abdominal and calf skinfold measures.

Following the pre-training assessment, PE classes were randomly assigned to one of the three programs (MRT, N = 67; MRT+E, N = 74; or Control, N = 232). For all three programs, 80-minute class sessions were held three times a week. Students in the MRT and MRT+E experimental groups were trained by the MRT system. For the MRT program, each PE session included a 10-15 minute warm-up segment with light cardiovascular activities and dynamic stretching, followed by the MRT specific segment of approximately 20-30 minutes conducted and supervised by trained research assistants. The remainder of each class session was taught by the physical education teacher of the class, following the usual PE curriculum. The first week of the intervention period was devoted to teaching the

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

students the correct exercise and spotting techniques of 18 basic MRT exercises. In the following four weeks 1 to 2 new MRT exercises were introduced in each class session. The MRT+E program performed the same 20-30 minute MRT segment in each class period as the MRT group, with an additional 20-30 minute period devoted to cardiovascular endurance training. Cardiovascular activities included walking, jogging, step aerobics and aerobic kick-boxing, attempting to maintain students' heart rate above 60% of their estimated maximum heart rate for at least 15 minutes. The Control group followed the general PE curriculum as taught by the physical education teacher of the class. In general, physical education classes focused on skill development for various individual physical activities (i.e. bowling, badminton, tennis, table tennis, golf, various track and field events) and team physical activities (i.e. soccer, basketball, softball/baseball, volleyball, floor hockey), as well as participation in leisure activities (i.e. hiking) and sport tournaments.

MRT Intervention Protocol

All subjects in the MRT and MRT+E experimental groups performed the same training routine, independent of pre-training performance. All sessions were organized in a tri-set or mini-circuit training format, where three to four exercises were performed in succession with short (20-30 second) rest intervals between each exercise. The volume and intensity of the training sessions were adjusted weekly according to the training plan, which was designed to apply the principals of progressive overload. Subjects performed a total of 12 sets per session at the beginning of the program, which was then progressively increased up to 28 sets by the latter weeks of the intervention. Generally, participants performed six large upper- and lower-body muscle group exercises during each session with two to four sets of eight to fourteen repetitions. Applying these repetitions was perceived to provide sufficient stimuli for simultaneous improvements in muscular strength and muscular endurance, which was thought necessary to achieve improvements in the selected Fitnessgram tests. Applied MRT exercises varied from session to session, but the program design focused on the balanced development of the large upper- and lower-body muscle groups. A sample program plan is presented in Table 2, and Table 3 presents the used exercise × set × repetition scheme for the 18-week program.

A simple example for an MRT movement is the resisted standing biceps curl (Figure 1). MRT and MRT+E group subjects used a PVC pipe for this exercise (held by the lifters) with the resistance provided by their partners (spotters). The lifter assumed the appropriate lifting position for the exercise with the PVC pipe while the spotter knelt in front of the lifter with his/her hands on the pipe. As the lifter performed flexion of the elbows, the spotter provided resistance while allowing smooth and continuous movement. In the eccentric phase of the movement, the spotter applied more force and pulled the pipe downward in a controlled manner while the lifter attempted to resist and slow the descent of the pipe.

Trained research assistants supervised all training sessions, monitored subjects for safety, and provided motivation. The speed of movement for the MRT exercises was controlled (approximately 3 seconds for each eccentric and concentric phase), which assisted MRT spotters with applying the appropriate resistance. The trained research assistants that supervised the experimental groups were also responsible for monitoring exercise techniques and encouraging the lifters and the spotters for greater effort.

MRT exercises designed for the experimental groups closely mimicked the traditional weight resistance training exercises. A priority when designing MRT exercises was to provide the spotters with the mechanical advantage over the lifters. The spotter's ability to generate greater force than the lifter, thus controlling the applied resistance throughout the range of motion is critical when applying MRT. A well-designed MRT exercise enables a weaker spotter to provide sufficient resistance for a stronger lifter thereby allowing

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

individuals of differing strength to be partners (8). Furthermore, for this study attention was given during the MRT exercise design process to avoiding inappropriate body contact between spotters and lifters. Therefore, students performed all exercises with the use of straps or PVC pipes and no direct body contact occurred between spotters and lifters.

Statistical Analyses

All statistical analyses were performed using the SAS version 9.1.3 (SAS Institute Inc., Cary, NC) software package. Pre-, midterm- and post-test data were analyzed using a General Linear Mixed Model Analysis for repeated measures with Tukey's post-hoc procedure for the mean comparisons. Pre- versus midterm-test, midterm- versus post-test, and pre- versus post-test results were compared to evaluate the physical changes of the students and trace the necessary time-span for such changes. Criterion alpha level for significance was set at $p \leq 0.05$ for all analyses.

Results

Pre-training assessments were recorded for 373 students (MRT, N = 67; MRT+E, N = 74; Control, N = 232). However, complete data (pre-, midterm-, and post-test) were collected for 222 students (122 males and 100 females). Over the 18-week intervention period, 127 students were lost from the study primarily because of students dropping out of PE. The greatest loss of participants occurred in the Control group, where 78 students either dropped the PE class or transferred to a different school, 1 student withdrew consent to participate in the study and 3 students became pregnant. While no students withdrew from either experimental group, the MRT group had 1 student drop PE and 2 students became pregnant. The MRT+E group had 5 students drop PE during the first 9 weeks of the intervention and a full class of 36 students were lost immediately after the midterm-test, as the school curriculum mandated only a half semester of PE, followed by a half semester of health studies. One MRT+E student became pregnant. In addition, 24 subjects (1 MRT, 2 MRT+E, and 21 Control students) failed to attend the post-test data collection and were not included in the data analyses. A total of 222 students were included in the data analyses for the MRT (N = 63), MRT+E (N = 30), and Control (N = 129) groups. Pre-test measures showed no significant differences between MRT, MRT+E and Control groups for age, height, weight, or BMI measures ($p > 0.91$) (Table 1).

At baseline, there were no significant differences between groups for the one-mile run ($p > 0.27$), trunk lift ($p > 0.20$), push-up ($p > 0.07$), modified pull-up ($p > 0.36$), or skinfold ($p > 0.42$) measures. For the curl-up measure, the MRT and MRT+E groups performed significantly better than the Control group ($p = 0.0002$). For the flexed-arm hang test, an error occurred when collecting pre-test data for the MRT+E group, thus these data were eliminated from the analysis. MRT and Control groups performed similarly at pre-test for the flexed-arm hang ($p > 0.34$).

Body Mass Index calculations indicated no significant differences between groups averaged across pre-, midterm- and post-tests ($p > 0.99$). Averaged across the three groups, there were no significant changes in BMI from pre- to midterm-test ($p > 0.15$) and pre- to post-test ($p > 0.83$), but a significant change from midterm- to post-test ($p < 0.05$) was observed. For the curl-up measure, differences between groups remained significant both at midterm- and post-test, as MRT and MRT+E groups performed significantly better than the Control group ($p < 0.0001$). Although curl-up improvements from pre- to midterm-test and pre- to post-test were significant when averaged across all three groups ($p < 0.0001$), MRT and MRT+E groups showed greater improvements than the Control group.

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

One-mile run measures indicated significant differences between groups at midterm-test ($p < 0.011$) and post-test ($p < 0.0001$) with MRT and MRT+E groups performing significantly better than the Control group. The MRT group showed some improvement from pre- to midterm- and pre- to post-test, but these changes were not significant ($p > 0.17$). The MRT +E group showed a significant improvement from pre- to midterm- and pre- to post-test ($p < 0.002$). The Control group showed a significant decrement in the one-mile run performance from pre- to post-test and from midterm- to post-test ($p < 0.008$).

For the trunk lift measures, significant differences were observed between groups at midterm-test ($p < 0.004$) with the MRT+E group performing significantly better than the MRT and Control groups, but no significant differences were observed at post-test ($p > 0.11$). Although all three groups showed significant improvements for the trunk lift from pre- to midterm- and pre- to post-test ($p < 0.0001$), a greater improvement was observed for the MRT and MRT+E groups. Similarly, push-up measures also indicated a greater improvement for the MRT and MRT+E groups from pre- to midterm- and pre- to post-test, although all three groups showed significant improvements across tests ($p < 0.0001$). Significant differences between groups were observed for the push-up test both at midterm- ($p < 0.001$) and post-tests ($p < 0.003$), where MRT and MRT+E groups performed better than the Control group.

The flexed-arm hang measures showed no significant differences between groups at midterm- or post-tests ($p > 0.13$), although both MRT and MRT+E groups performed better than the Control group. Both MRT and Control groups showed significant improvements from pre- to midterm- and pre- to post-test ($p < 0.002$), but greater improvements were observed for the MRT group. The MRT+E group also showed noticeable improvement from midterm- to post-test, but due to pre-test measurement error, no statistical significance could be determined.

For the modified pull-up test, significant improvements were observed averaged across all groups from pre- to midterm- and pre- to post-test ($p < 0.0001$), although the MRT and MRT+E groups showed greater improvements. Differences between groups for the modified pull-up were significant at midterm-test, as both MRT and MRT+E groups were significantly better than the Control group ($p < 0.05$). MRT and MRT+E groups performed the modified pull-up better at post-test as well, although differences were not significant ($p > 0.16$). For the skinfold thickness measures no significant differences between groups were observed at any assessment ($p > 0.42$). However, while the MRT+E group showed a relatively unchanged measure from pre- to midterm- and pre- to post-test ($p > 0.68$), an increased skinfold thickness was observed for both MRT ($p = 0.0002$) and Control groups ($p < 0.0001$) across assessment points. Pre-, midterm- and post-test summary statistics for all groups are presented in Table 4.

Discussion

This study investigated the effects of a Manual Resistance Training (MRT) program implemented in school-based physical education on the cardiovascular and muscular fitness as well as the body composition of adolescents. To our knowledge, this was the first study to implement an MRT program into a PE setting. The major study findings were that experimental subjects in the MRT and MRT+E groups showed greater improvements than the Control subjects for all six of the selected Fitnessgram assessments. Although, with the exception of the curl-up measure, no differences were observed between groups at pre-test, MRT and MRT+E groups were significantly better than the Control group at midterm-test in four measures (one-mile run, curl-up, push-up, modified pull-up) and at post-test in three measures (one-mile run, curl-up, push-up). These results clearly indicate that subjects

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

trained by the MRT program improved their fitness to a greater extent than those subjects who attended their regular PE classes. Subjects who were exposed to additional cardiovascular training (MRT+E group) achieved greater improvements for the one-mile run performance than the other two groups. However, an important observation was that while the MRT group subjects achieved some noticeable improvements in their one-mile run performance, Control subjects' running performance declined over the 18-week period.

A limitation of the present study was the unexpected high drop-out rate experienced in the Control and the MRT+E groups. The majority of the drop-outs in the Control group occurred within the first two weeks of the intervention period and was due to administrational errors in the experimental high schools. A large number of students, who were enrolled in PE and recruited into the present study, were then transferred to other classes or even to other schools within the school district shortly after the beginning of the intervention. In addition, an entire class of 36 students was lost from the MRT+E protocol following the midterm-test, because their physical education class was only a half semester (one academic quarter) and the school required these students to attend a health study course in the following quarter. Despite direct inquiries with school administrators, school district officials, and physical education teachers about class scheduling when identifying the intervention schools, we were unaware of the quarter system used for this PE class prior to initiating the intervention. The researchers contend that valuable data were lost with the drop-out of these 36 MRT+E subjects and we acknowledge that the final findings of the study may have been affected. Importantly, 30 students remained in the MRT+E group and this sample size was sufficient to complete statistical comparisons.

Improvements in the experimental subjects' muscular fitness were not surprising. The MRT system has been found effective for improving the muscular strength and endurance of adults (7,19). Our laboratory has reported the MRT system to be effective for improving the muscular fitness of college age adults (8). Also, previous research has shown that resistance training can be effective for increasing the strength of children and adolescents (9,12,16). The greater gains experienced by the MRT experimental subjects of the present study are likely due to the increased demands of the added resistance training. Similar to adults, previous research has suggested that children and adolescents may have a training threshold to overcome to improve muscular strength (12). Likely, the Control subjects that participated in regular PE classes did not receive adequate stimuli to reach these threshold levels; whereas the added MRT program was sufficient to surpass the threshold necessary for strength gains in the experimental subjects. A possible explanation for the slight strength increase observed in the Control group may be due to an exercise learning effect. All subjects may have shown some improvements due to learning and thus better execution of the Fitnessgram testing protocols across the tests. However, any learning effects were likely to have occurred similarly for all three groups; therefore, the significantly greater improvements of the experimental groups are probably due to genuine physiological and musculoskeletal adaptations.

Previous research has found that endurance training leads to the ability to exercise longer at a given exercise intensity or to exercise at a higher intensity for a certain duration (18). The present study supports this because while both MRT groups improved their one-mile run performance, the MRT+E group experienced the greatest improvement. The improved one-mile run performance observed for the MRT group may have occurred because of increases in muscle endurance that have been reported to occur in children who participate in resistance training programs (21). However, the added cardiovascular training component clearly contributed to the better running performance for the MRT+E subjects. An interesting observation was the decrease of one-mile performance for the Control group. A possible explanation for this is termed resentful demoralization (24), referring to the

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

possibility that subjects who were not selected for the experimental groups may have become unmotivated and discouraged to run at their full capacity.

An interesting study finding was that no significant changes were observed over the 18-week intervention period for either the body composition values measured by the skinfold thickness or the BMI calculations. Prior to the experiment it was hypothesized that body composition may improve for the two experimental groups, especially for the MRT+E group. However, midterm- and post-test measurements did not support our hypothesis, as an actual increase was observed in skinfold thickness in all three groups. Although the increase was minimal for the MRT+E group, skinfold measurements indicated significantly worse body composition values for both the MRT and Control groups. BMI values were essentially unchanged for all three groups across the study. Apparently, even a noticeable improvement in the experimental subjects' fitness level was not effective enough to elicit positive changes in body composition. Although the study subjects were asked to maintain their life-style, a shortcoming of our intervention was the lack of a controlled nutrition component. Despite the positive changes in physical fitness measures, it is likely that eating habits and other lifestyle factors of the subjects outside the physical education classes prevented any improvement in body composition.

Practical Applications

The poor levels of physical fitness among adolescents may be attributed to the reduced amount of time spent in PE classes resulting from the decline in physical education requirements between grades 8-12 (17). Many investigators have attempted to implement programs into the physical education curriculum with various levels of success (6,23,25). The unique challenge of the present study was to design a resistance training program that was not only effective and safe for adolescents, but required minimal equipment, could be performed in regular PE settings (i.e. no weight-room required), and required little time from the given class session. The implemented MRT program met these expectations. While physical education programs that focus solely on skill development for individual and team sports, and participation in leisure activities and sport tournaments appear less likely to improve muscular and cardiovascular fitness in adolescents, PE programs enhanced with cardiovascular training and complemented with Manual Resistance Training can be effective in improving adolescents' physical fitness in a short-period of time. A disadvantage of MRT is that training effectiveness greatly depends on the spotter's ability to provide appropriate resistance while simultaneously allowing for the full range of motion. To achieve appropriate levels of applied resistance and range of motion, spotters may require some level of training. Once proper spotting is mastered, MRT may be particularly appropriate and useful in physical education programs, as it requires minimal set up, relatively inexpensive equipment, and can be applied in non-weight room based training settings and in areas otherwise not suitable for resistance training, including indoor (classrooms, gymnasiums, etc.) or outdoor (field) environments.

Acknowledgments

This research was supported by Grant Number P20MD002287 from the National Institutes of Health (NIH), National Center on Minority Health and Health Disparities (NCMHD) through the Hispanic Health Disparities Research Center (HHDRC) and by Grant Number 5G12RR008124 from the NIH, Research Centers in Minority Institutions (RCMI). The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH, NCMHD, RCMI or HHDRC. We thank the collaborating physical education teachers for their assistance.

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

References

1. Andersen RE, Crespo CJ, Bartlett SJ, Cheskin LJ, Pratt M. Relationship of physical activity and television watching with body weight and level of fatness among children: results from the Third National Health and Nutrition Examination Survey. JAMA 1998;279:938–942. [PubMed: 9544768]
2. Centers for Disease Control and Prevention. Physical activity levels among children aged 9–13 years—United States, 2002. Morbidity and Mortality Weekly Report 2003;52:785–788. [PubMed: 12931076]
3. Coleman KJ, Heath EM, Alcala IS. Overweight and aerobic fitness in children in the United States/Mexico border region. Rev Panam Salud Publica 2004;15:262–271. [PubMed: 15193182]
4. Committee on Progress in Preventing Childhood Obesity. Progress in Preventing Childhood Obesity: How Do We Measure Up?. Washington, D.C.: Institute of Medicine of the National Academies: National Academies Press; 2007. p. 476
5. Crespo CJ, Arbesman J. Obesity in the United States. Phys Sportsmed 2003;31:23–29. [PubMed: 20086444]
6. Davis SM, Clay T, Smyth M, Gittelsohn J, Arviso V, Flint-Wagner H, Rock BH, Brice RA, Metcalfe L, Stewart D, Vu M, Stone EJ. Pathways curriculum and family interventions to promote healthful eating and physical activity in American Indian schoolchildren. Prev Med 2003;37:S24–34. [PubMed: 14636806]
7. Dombroski, RT.; Henderson, JM. Partner resistance exercises versus calisthenics for upper body strength improvement. Third Annual Meeting of American Medical Society of Sports Medicine; Ranch Mirage, CA. 1994;
8. Dorgo S, King GA, Rice CA. The effects of manual resistance training on improving muscular strength and endurance. J Strength Condition Res. in press.
9. Faigenbaum AD. Strength training for overweight teenagers. Strength Condition J 2002;24:67–68.
10. Faigenbaum AD. Youth resistance Training. President's Council on Physical Fitness and Sports. Res Digest 2003;4
11. Faigenbaum AD, Kraemer WJ, Cahill B, Chandler J, Dziados J, Elfrink LD, Forman E, G M, M L, N M, Roberts S. Youth Resistance Training: Position Statement Paper and Literature Review. Strength and Condition 1996;18:62–76.
12. Faigenbaum AD, Westcott WL, Loud RL, Long C. The effects of different resistance training protocols on muscular strength and endurance development in children. Pediatrics 1999;104:e5. [PubMed: 10390291]
13. Falk B, Tenenbaum G. The effectiveness of resistance training in children. A meta-analysis. Sports Med 1996;22:176–186. [PubMed: 8883214]
14. Goran MI, Reynolds KD, Lindquist CH. Role of physical activity in the prevention of obesity in children. Int J Obes Relat Metab Disord 1999;23 3:S18–33. [PubMed: 10367999]
15. Hunter GR, Bamman MM, Hester D. Obesity-prone children can benefit from high-intensity exercise. Strength Condition J 2000;22:51–54.
16. Ingle L, Sleap M, Tolfrey K. The effect of a complex training and detraining programme on selected strength and power variables in early pubertal boys. J Sports Sci 2006;24:987–997. [PubMed: 16882633]
17. Johnston LD, Delva J, O'Malley PM. Sports participation and physical education in American secondary schools: current levels and racial/ethnic and socioeconomic disparities. Am J Prev Med 2007;33:S195–208. [PubMed: 17884568]
18. Jones AM, Carter H. The effect of endurance training on parameters of aerobic fitness. Sports Med 2000;29:373–386. [PubMed: 10870864]
19. Kraemer WJ, Mazzetti SA, Nindl BC, Gotshalk LA, Volek JS, Bush JA, Marx JO, Dohi K, Gomez AL, Miles M, Fleck SJ, Newton RU, Hakkinen K. Effect of resistance training on women's strength/power and occupational performances. Med Sci Sports Exerc 2001;33:1011–1025. [PubMed: 11404668]
20. Nelson MC, Neumark-Stzainer D, Hannan PJ, Sirard JR, Story M. Longitudinal and secular trends in physical activity and sedentary behavior during adolescence. Pediatrics 2006;118:e1627–1634. [PubMed: 17142492]

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

21. Ramsay JA, Blimkie CJ, Smith K, Garner S, Macdougall JD, Sale DG. Strength training effects in prepubescent boys. Med Sci Sports Exerc 1990;22:605–614. [PubMed: 2233199]

22. Rosamond W, Flegal K, Friday G, Furie K, Go A, Greenlund K, Haase N, Ho M, Howard V, Kissela B, Kittner S, Lloyd-Jones D, Mcdermott M, Meigs J, Moy C, Nichol G, O'Donnell CJ, Roger V, Rumsfeld J, Sorlie P, Steinberger J, Thom T, Wasserthiel-Smoller S, Hong Y. Heart disease and stroke statistics--2007 update: a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Circulation 2007;115:e69–171. [PubMed: 17194875]

23. Sallis JF, Mckenzie TL, Alcaraz JE, Kolody B, Faucette N, Hovell MF. The effects of a 2-year physical education program (SPARK) on physical activity and fitness in elementary school students. Sports, Play and Active Recreation for Kids. Am J Public Health 1997;87:1328–1334. [PubMed: 9279269]

24. Shadish, WR.; Cook, TD.; Campbell, DT. Experimental and Quasi-Experimental Designs for Generalized Causal Inference. Boston, MA: Houghton Mifflin Company; 2002. p. 623

25. Simons-Morton BG, Parcel GS, Baranowski T, Forthofer R, O'Hara NM. Promoting physical activity and a healthful diet among children: results of a school-based intervention study. Am J Public Health 1991;81:986–991. [PubMed: 1854016]

26. Sothern MS, Loftin JM, Udall JN, Suskind RM, Ewing TL, Tang SC, Blecker U. Inclusion of resistance exercise in a multidisciplinary outpatient treatment program for preadolescent obese children. South Med J 1999;92:585–592. [PubMed: 10372852]

27. Vetter RE, Dorgo S. Effects of partner's improvisational resistance training on dancers' muscular strength. J Strength Condition Res. in review.

28. Welk, GJ.; Meredith, MD., editors. Fitnessgram / Activitygram Reference Guide. Dallas, TX: The Cooper Institute; 2008.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

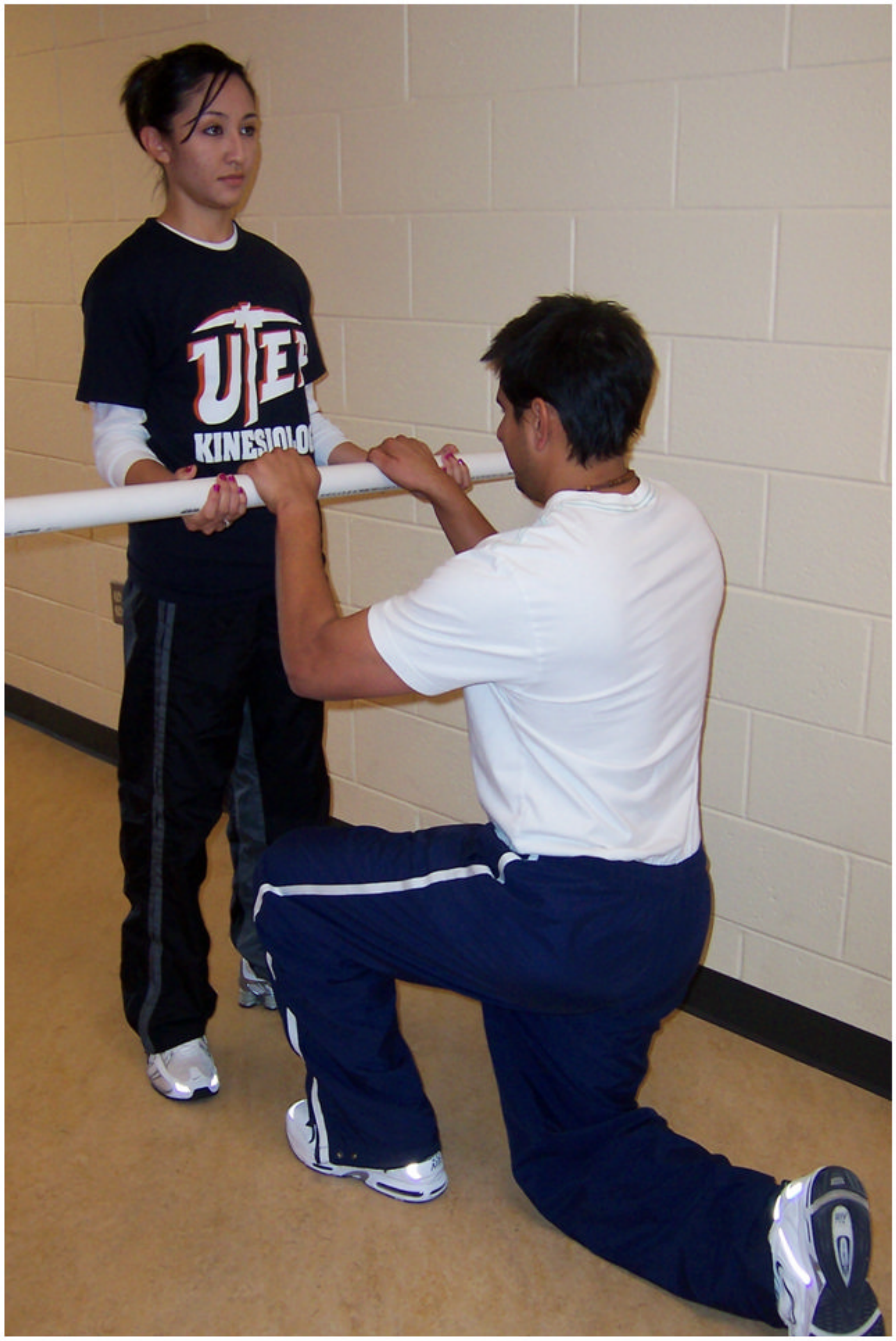

Figure 1.
Manual Resistance Training standing biceps curl exercise demonstrated by two subjects

NIH-PA Author Manuscript
NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 1

Mean (± SD) pre-training descriptive characteristics of the Manual Resistance Training (MRT), Manual Resistance Training plus cardiovascular endurance training (MRT+E), and the physical education control (Control) groups.

GROUP	N	Age (y)	Height (cm)	Body Mass (kg)	Body Mass Index (kg/m^2)
MRT	63	16.0 ± 1.2	163.6 ± 8.7	65.1 ± 19.0	24.2 ± 6.1
MRT+E	30	15.9 ± 1.2	161.8 ± 8.2	62.1 ± 17.2	23.6 ± 5.9
Control	129	15.8 ± 1.1	164.3 ± 8.5	67.2 ± 19.9	24.8 ± 6.4

No significant group difference ($p > 0.05$).

NIH-PA Author Manuscript
NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 2

A 1-week sample training program for the Manual Resistance Training (MRT) and Manual Resistance Training plus cardiovascular endurance training (MRT+E) groups.

Day 1	Day 2	Day 3
Tri-set 1	**Tri-set 1**	**Tri-set 1**
Resisted squat	Resisted seated chest press	Resisted bent-over row
Resisted seated row	Resisted lat pulldown	Resisted leg extension
Resisted overhead triceps extension	Resisted step lunge	Resisted shoulder press
Tri-set 2	**Tri-set 2**	**Tri-set 2**
Resisted seated fly	Resisted Romanian deadlift	Resisted good-morning
Resisted shoulder press	Resisted upright row	Resisted lying triceps extension
Resisted seated back extension	Resisted extended arm pressdown	Resisted standing biceps curl

Tri-set: three exercises were performed in succession with short (20-30 seconds) rest intervals between each exercise.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Table 3

Experimental 18-week training program design for the Manual Resistance Training (MRT) and Manual Resistance Training plus cardiovascular endurance training (MRT+E) groups.

Week #	circuit × exercise × set × repetition scheme	Total # of sets
Week 1-2	2 circuits × 3 exercises × 2 sets × 10 reps	12
Week 3-4	1 circuit × 3 exercises × 3 sets × 10 reps and 1 circuits × 3 exercises × 2 sets × 10 reps	15
Week 5-6	2 circuits × 3 exercises × 3 sets × 12 reps	18
Week 7-8	2 circuits × 3 exercises × 2 sets × 14 reps	18
Week 9-10	2 circuits × 3 exercises × 3 sets × 12 reps	18
Week 11-12	1 circuit × 3 exercises × 4 sets × 10 reps and 1 circuit × 3 exercises × 3 sets × 12 reps	21
Week 13-14	2 circuits × 3 exercises × 4 sets × 12 reps	24
Week 15-16	1 circuit × 4 exercises × 4 sets × 8 reps and 1 circuit × 3 exercises × 4 sets × 12 reps	28
Week 17-18	2 circuits × 3 exercises × 4 sets × 14 reps	24

NIH-PA Author Manuscript
NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 4

Mean (± SE) pre-, midterm-, and post-training fitness test measures for the Manual Resistance Training (MRT), Manual Resistance Training plus cardiovascular endurance training (MRT+E), and the physical education control (Control) groups.

Test	Group	Pre	Midterm	Post
BMI (kg/m^2)	Control	24.9 ± 0.6	24.7 ± 0.6	24.6 ± 0.6
	MRT	24.4 ± 0.8	24.8 ± 0.8	24.5 ± 0.8
	MRT+E	24.8 ± 1.2	25.1 ± 1.2	24.7 ± 1.2
1-Mile run (seconds)	Control	803.8 ± 25.7	793.2 ± 25.7	930.4 ± 25.7*†
	MRT	734.0 ± 31.0	685.8 ± 31.0‡	726.5 ± 31.0‡
	MRT+E	767.7 ± 40.6	671.2 ± 40.6‡	650.9 ± 40.6*‡
Curl-up (repetition)	Control	14.8 ± 1.5	25.0 ± 1.5*	21.2 ± 1.5*
	MRT	19.2 ± 2.2‡	37.6 ± 2.2*‡	31.2 ± 2.2*‡
	MRT+E	25.3 ± 3.1‡	45.0 ± 3.1*‡	43.3 ± 3.1*‡
Trunk lift (cm)	Control	21.7 ± 0.5	23.0 ± 0.5*	23.9 ± 0.5*
	MRT	20.8 ± 0.7	23.8 ± 0.7*	25.6 ± 0.7*
	MRT+E	20.2 ± 0.9	26.6 ± 0.9*‡	25.3 ± 0.9*
Push-up (repetition)	Control	8.6 ± 0.7	10.8 ± 0.7*	10.0 ± 0.7*
	MRT	9.7 ± 1.1	15.1 ± 1.1*‡	12.6 ± 1.1*‡
	MRT+E	11.9 ± 1.5	16.8 ± 1.5*‡	16.6 ± 1.5*‡
Flexed-arm hang (seconds)	Control	5.6 ± 1.1	7.3 ± 1.1*	7.2 ± 1.1*
	MRT	6.5 ± 1.5	11.6 ± 1.5*	11.9 ± 1.5*
	MRT+E	12.5 ± 2.2	8.3 ± 2.2	11.8 ± 2.2
Modified Pull-up (repetitions)	Control	6.8 ± 0.6	8.8 ± 0.6*	8.5 ± 0.6*
	MRT	7.6 ± 0.9	12.1 ± 0.9*‡	10.3 ± 0.9*
	MRT+E	7.8 ± 1.2	9.9 ± 1.2‡	10.9 ± 1.2*
Skinfold (mm)	Control	60.4 ± 2.7	65.7 ± 2.7*	67.9 ± 2.7*
	MRT	58.0 ± 3.9	64.6 ± 3.9*	64.9 ± 3.9*
	MRT+E	65.5 ± 5.6	65.3 ± 5.6	66.0 ± 5.6

Skinfold values are sum of triceps, abdominal, and calf folds.

*Significantly different (p ≤ 0.05) than Pre-training measure.

†Significantly different (p ≤ 0.05) than Midterm measure.

‡Significantly different (p ≤ 0.05) than Control group.