Resistance Training for Adolescents

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KEYWORDS

• Resistance training • Strength training • Periodization
• Load • Repetitions • Sets

The term resistance training (RT) refers to a method of physical conditioning that uses progressively increasing resistive loads and various training techniques to achieve desired muscle strength, power, muscle hypertrophy, local muscular endurance, or a combination thereof (**Table 1**).[1–8] Various techniques are used in RT to increase work demands of the muscles (**Table 2**).[5–8] Often, the terms resistance training, strength training, weight training, and weight lifting are used interchangeably and inappropriately. Strength training is one of the specific goals achievable through various RT techniques. Weight lifting is a competitive sport that includes the snatch and clean and jerk lifts, not recommended for adolescents.[7] Similarly, participation in competitive power lifting and body building is not recommended for adolescents.[7]

RT is recommended as an integral component of any regular exercise program. The design of a RT program depends up on the specific goals of RT. The goal of a RT program can be to improve muscle strength, increase power, increase muscle bulk or size, enhance muscle endurance, or a combination of any of these goals. A RT program that is specifically designed as part of sport-specific training and conditioning takes into consideration the relative aerobic and anaerobic demands of the sport, and relative importance of achieving muscle strength, power, muscle hypertrophy, or local muscular endurance.[5] Therefore, sport-specific training and conditioning is more complex, and the training program should be designed and supervised by appropriately qualified professionals. This article reviews the general recommendations for RT for health-related physical fitness. Health-related physical fitness generally consists of various aspects of regularly recommended exercises that result in good health. In addition to RT, other components of health-related physical fitness exercises include aerobic exercise, flexibility exercises, and stretching. The discussion

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Table 1 RT goals	
Strength	Maximal force that a muscle or muscle group generates at a specific velocity of movement
Power	The rate (how fast) a muscle or group of muscles can perform a given task. (Power = work/time; work = force exerted on an object × the distance the object moves in the direction in which the force is exerted)
Hypertrophy	Increase in the size (cross-sectional area) of the muscle; primarily results from hypertrophy of muscle fibers
Local muscular endurance	The ability of a muscles or muscle group to continue to perform contractions against a submaximal resistance

Data from Refs.[1,2,4,5]

here focuses on adolescents aged 13 to 18 years who have reached Tanner stage 3 and above.[1]

SAFETY OF RESISTANCE TRAINING

If appropriate for the emotional and developmental stage, RT poses minimal risk of injury to adolescents. Some studies have reported injuries resulting from RT; however, these are minor or occurred as a result of improper load or exercise technique.[9–12] Although there are acknowledged risks with RT for adolescents, these risks are no greater than the risks of participation in sport and recreational activities.[1] Injuries reported in RT do not occur any more frequently in youth than in adults.[13,14] Zaricznyj and colleagues[14] reported that RT accounted for less than 1% of all injuries, while football and basketball accounted for 19% and 15% of injuries, respectively.

Injuries from RT to growth plates, articular cartilage, and apophysis remain a concern in children and adolescents, because these areas are relatively weaker and therefore more susceptible to injuries from excess stress. The likelihood of growth plate or cartilage damage may be higher in adolescents than in preadolescents, because the growth cartilage is more resilient to shearing forces in preadolescents.[15] Although the potential risk of injury to growth cartilage may exist, RT has not been shown to adversely affect skeletal growth or maturation in adolescents.[16,17]

The potential for soft-tissue overuse injuries is also a concern in adolescents. Overuse injuries associated with RT in adolescents are not adequately documented; however, the incidence of lower back pain in adolescents is significant enough to warrant concern.[1] A properly designed RT program that focuses on strength and flexibility may help alleviate lower back pain.[1]

Most published reports suggest that the benefits of RT in adolescents far outweigh any concerns for potential injuries.[18,19] The use of weight machines, elastic bands, or

Table 2 Examples of techniques used in RT	
Techniques	**Examples**
Load-bearing exercises	Climbing
Specific bodyweight exercises	Curl-ups, press-ups, jumping, hoping
Use of resistive materials	Stretch or elastic bands of various resistance, weight machines, free weights

body weight all have been shown to be effective in RT.[17,20–26] Resistance training in children and adolescents has been shown to increase strength by 13% to 30%.[27,28] In addition to improved physical fitness, a well-designed RT program can contribute to improved psychosocial well-being and help establish and promote beneficial exercise habits at an early age.[1]

Properly supervised RT is an integral component of health-related and sport specific training and conditioning.[1,29] RT can be initiated at almost any age for children as long as they are emotionally and physically ready to undertake such a program—generally 7 to 8 years of age.[1,7] Supervision and instructions should be provided by qualified professionals who have training and background in RT techniques and an understanding of the unique needs, both physical and psychological, of children and adolescents.[1,7] Supervision should include feedback about form, speed of movement, breathing techniques, and proper lifting or performing the movements. Instructions in developing correct resistance training techniques will assist adolescents in achieving RT goals, limit the potential for injury, and promote program adherence.[1,30] In instances where instruction in complex techniques is included, more than one supervisor may be needed, thereby increasing the supervisor-to-adolescent ratio in the weight room. Supervisor or instructor to adolescent ratios of 1:10 to 1:25 can be appropriate, depending upon the complexity of exercises and the maturity of the adolescents being supervised.

EVALUATION BEFORE STARTING RT

Before starting RT, the adolescent should be evaluated to identify any medical conditions that may require appropriate modification of the RT program. History should include information about nutrition and use of supplements such as creatine and drugs such as anabolic–androgenic steroids.

It is important to assess the physical, cognitive, and psychosocial developmental status of the adolescent. The adolescent should have realistic expectations from RT. The adolescent should understand that to achieve the desired goals of RT, exercises need to be done on a regular basis for a long period of time. The adolescent should understand the importance of correct form and techniques of RT exercises and appropriate supervision and guidance by qualified professionals should be provided to reduce the risk of injury and to progress toward desired goals.

Before beginning an RT program, it is essential to ascertain the adolescent's RT status, so as to design a program that matches the adolescent's experience and current physical fitness. Adolescents can be placed into one of three groups based on their previous level of RT experience: novice or beginner, intermediate, and advanced. Novices or beginners are adolescents with limited (<2 to 3 months) to no resistance training experience; adolescents in the intermediate group are those who have had approximately 3 to 12 months of training experience. Adolescents with 12 or more months training experience are considered advanced.[1,5] When determining the exercises for the RT program, it is imperative that the exercises are appropriate for the adolescent's physical development, fitness level, and RT status.[1]

COMPONENTS OF AN RT PROGRAM

Proper warm-up and cool-down periods, level of intensity, frequency of training sessions, order of exercises, volume of exercise, and rest periods are main considerations in designing a RT program.[1,4,5,29,30] RT programs for adolescents also should

include specific educational objectives, instructions in weight room etiquette, and desired performance outcomes.[1,29]

Warm-up

Warm-up consists of movements that prepare the body before the desired activity. A warm-up period is recommended to increase the range of joint motion, raise body temperature, and enhance awareness of body position. The warm-up period usually consists of two phases: general and specific. The general phase consists of 5 to 10 minutes of general activities to increase the heart rate, muscle temperature, and respiratory rate, and decrease joint viscosity.[31] The specific warm-up consists of activities similar to the movements performed during the resistance training exercises, lasting for approximately 8 to 12 minutes.[32] Dynamic activities during the warm-up period have been shown to assist in enhancing power performance for youth.[1,33–35]

Cool-down

The cool-down period occurs after the exercise session and consists of dynamic exercises similar to the warm-up period. The aims of the cool-down period are to facilitate the elimination of waste products from the muscles, and to return the heart rate and respirations to preactivity levels. In addition, a cool-down period should include a flexibility component that includes static stretching. Stretching exercises after activity can increase flexibility while increasing performance and reducing the risk of injury over the long term.[36,37] Typically, the cool-down period lasts approximately 5 minutes and is also an appropriate time to reflect on the day's activities and focus on training objectives for future exercise sessions.[33–35]

Order of Exercises

Generally, the exercises selected should start with single-joint, simple movements and progress to multijoint and complex movements. Progression to the complex exercises should be based upon demonstration of proper exercise technique, confidence, and attainment of goals and objectives. In more experienced adolescents, multijoint exercises, performed using proper techniques and lower weights, can be initiated in early exercise sessions. Within a training session, large muscle groups typically should be exercised before small muscle groups, while multijoint exercises should be performed before single-joint exercises.[1,4,5] This pattern helps reduce the risk of injury by stressing neuromuscularly demanding exercises at the beginning of a session when fatigue is minimal.[1]

Load or Intensity

The training load refers to the amount of weight lifted for that specific resistance exercise.[5] As the load becomes heavier, the number of repetitions decreases. Conversely, more repetitions can be accomplished with lighter loads. The load usually is described as a percentage of 1 repetition maximum (1 RM) or as the maximum weight lifted in 1 repetition.[5,32] The weight should be lifted through the entire joint range of motion. The use of a 1 RM to determine the load is more appropriate for experienced resistance trained individuals, whereas, a 5 RM or up to 10 RM method is preferred for less experienced individuals and adolescents.[1,5,6] Determining the RM depends upon the goals and demands of the sport.[32]

Another method used to determine the percent of maximum load lifted during an exercise session is the RM equivalent. The RM equivalent is calculated as[38–41]: RM equivalent = (weight lifted $\times$ number of reps $\times$ 0.03) + weight lifted. For example, an RM equivalent for an adolescent who lifted 125 lb during an inclined bench press

exercise a total of 8 times would be calculated as: (125 × 8 × 0.03) + 125 = 155. Although not as accurate, the RM equivalent procedure may be best suited for inexperienced adolescents.

The relationship between possible RM and percentages of 1 RM varies with the amount of muscle mass needed to perform the exercise (eg, a leg press requires more muscle mass than a knee extension). Because different muscles or muscle groups exert different amounts of force depending up on their mass and strength, the load for a given number of repetitions can vary depending upon the muscles or muscle group involved in a particular exercise.[5] The velocity of muscle contraction, that is how fast or slow a muscle contraction is achieved, during dynamic muscle action is inversely related to the exercise load during maximal muscle contraction.[4] The velocity of muscle contraction affects the neural, hypertrophic, and metabolic adaptations to RT exercises.[4]

Sets and Repetitions

Repetitions refer to the number of times a weight is lifted in a set; conversely, a set consists of the number of repetitions performed between rest periods.[5] In RT programs, the number of repetitions and sets are manipulated according to the goal of the RT and desired outcomes for the adolescent. The number of sets and repetitions may vary for different muscles or muscle groups. For example, it generally is recommended that adolescents perform three sets of six to eight repetitions for multijoint exercises, and two sets of 10 to 12 repetitions for single joint exercises.[1] Generally, multiple sets of RT exercises have been shown to be more effective than single-set exercises. The number of sets and repetitions do not have to be the same for all muscle groups or exercises.[1,4,5]

Frequency

The term training frequency refers to the number of training sessions completed in a given time period. Training frequency depends upon the experience, maturity, and training status of the adolescent, and sport or outcome requirements. Adolescents should begin RT with one to three sessions a week on nonconsecutive days. As the adolescent becomes more experienced, sessions can increase up to three times per week, but the load and rest periods may need to be manipulated for optimal recovery between sessions.[1]

Rest between two RT sessions should not exceed more than 3 days.[1–4] A split-routine regime allows for more frequent RT sessions. In a split routine, exercises involving different muscles or muscle groups are performed on different days. Exercises can be divided, for example, into upper body and lower body, in which upper body exercises are done on days 1 and 3, and lower body exercises are done on days 2 and 4. Similarly, exercises can be divided as push exercises (bench press, triceps extension) or pull exercises (lat pull down, biceps curl) and done on different days of the week.

Factors such as training volume, exercise intensity, exercise selection, nutrition, and sleep habits should be taken into consideration when determining the optimal recovery period between RT sessions.[1,4] As the number of training sessions increases, attention should be given to maintaining appropriate training habits, with less intense workouts interspersed throughout the week.

Rest Periods

The duration of rest periods between sets varies according to the specific goal of the RT, load lifted, and training status of the adolescent. For adults, the duration of rest

periods between sets varies from 2 to 5 minutes for multijoint exercises, depending upon the goal of the training. The duration of rest periods in adults may not be applicable to adolescents, however, because of differences in maturity, growth, and development. Studies have shown that adolescents may recover more quickly than adults for high-intensity, short-duration exercises.[42,43] Rest periods of approximately 1 to 3 minutes may suffice in adolescents for moderate-intensity RT depending upon the goal of resistance training.[1]

Volume of Exercise

The volume of exercise refers to the total amount of weight lifted during an exercise session.[4,5] Volume or load volume equals the total number of sets multiplied by the number of repetitions per set multiplied by the weight lifted per repetition.[2,4,5,32] If each set is performed using a different weight or load, the volume is calculated for each set, and then the volume for each set is added to obtain the total volume of the exercise session. Thus, the volume of the exercise session can be manipulated by altering number of sets, number of repetitions per set, or weight lifted per repetition. Variation in training volume is essential during long-term training for those who are more advanced in their training. Constant-volume exercise sessions may result in staleness and decreased adherence to training.

TYPES OF EXERCISES AND MUSCLE ACTIONS

Exercises can be considered core or assistance type based on the extent of the muscle areas involved.[5] Core exercises involve large muscle areas such the chest, shoulder, or back, whereas assistance exercises involves smaller muscle groups, such as the neck, upper arms, or lower legs. Core exercises involve two or more primary joints, whereas assistance exercises involve only one primary joint. In general, core exercises are relatively more important for sport-specific training.

The main types of muscle actions are summarized in **Table 3**.[2,4,5] RT programs should include both eccentric and concentric muscle actions.[1] Multiple joint exercises, such as the bench press or squat, allow for a greater amount of load to be lifted; therefore they are considered more effective for overall improvement in muscle strength. On the other hand, single-joint exercises such as knee extensions or knee curls allow for a relatively smaller amount of load to be lifted and are more useful for targeting specific muscles or muscle groups. In general, weight machines are considered relatively safer to use for adolescents. Use of weight machines allows one to perform multijoint exercises more easily than using free weights. Because machines stabilize the body, they limit movements about specific joints. This results in less neural activation compared to free weights, allowing for more free movement of specific joints.

Specific exercises should be designed to avoid imbalances in muscle strength between opposing muscle groups. While performing bilateral exercises, for example using a machine for chest press, the relative weakness of one side may be compensated for by the stronger side, resulting in muscle strength imbalance. Therefore, both unilateral and bilateral exercises should be included in the RT program.[4,5]

PRINCIPLES OF TRAINING PROGRESSION

Progressive overload, specificity, and program variation or periodization are the main principles of resistance training progression.[1–5]

Table 3
Types of muscle actions

Concentric	Muscle fibers shorten as the joint is moved through the range of motion For example lifting the weight during biceps curl Swimming and cycling involve predominantly concentric muscle actions
Eccentric	Muscle fibers lengthen as the joint is moved through the range of motion For example lowering the weight during biceps curl
Isometric	Muscle fiber length remains constant as the joint is moved through the range of motion
Isokinetic	Typically performed using isokinetic device or equipment Isokinetic device allows only single-joint movements Speed of movement through the range of joint motion is kept constant by the isokinetic device Because most sport and other activities require varying speed of movements, application of isokinetic training limited in sports training
Isotonic	Isontonic muscle action involves both concentric and eccentric components Muscle tension or muscle mass remains constant during the movement For example, lifting free weights or moving a person's body weight; the free weight or person's body weight remains the same, while the force needed to move the weight varies depending up on the joint angle and velocity of movement Tension generated in the muscle varies depending up on weight lifted, velocity of joint movement, strength of muscles involved, and type of muscle action

Data from Refs.[1–9,32]

Progressive Overload

Progressive overload refers to the gradual increase of load during RT. General guidelines for RT exercises are summarized in **Table 4**, and an example of a strength training program for beginners is outlined in **Table 5**.[1–8] It is necessary to progressively increase the load to continue to gain benefits from RT. Overall demands of RT on the body can be increased or decreased gradually by manipulating exercise load or intensity, number of repetitions, number of sets, velocity of muscle action, duration of rest periods, or total volume of exercise, depending upon the specific goals of RT.[1–8]

How an adolescent progresses through RT depends on the primary goal of the training. Intensity should increase progressively as the adolescent gains experience. A novice might start between 50% and 70% of a RM and eventually progress to 70% to 85% of a RM at the advanced level.[1] As experience is gained, the number

Table 4
Resistance training guidelines[a]

Goal	Load (% 1 RM)[b]	Sets	Repetitions	Rest Period
Strength	Moderate (75–85)	2–6	≤10	2–5 min
Power	Moderate (75–85)	2–5	3–8	2–5 min
Hypertrophy	Heavy (≥85)	3–6	6–12	30–90 s
Endurance	Light (≤70)	6–8	≥12	≤30 sec

[a] Range in values for different parameters reflect individual differences.
[b] Start with lighter loads, higher repetitions, and sets, and progress to heavier loads and fewer repetitions and sets.
Data from Refs.[1–9,29,32]

Table 5
Example of an adolescent strength training program for the beginner

Goal Sets	Primarily to increase muscle strength 1–3
Repetitions	10–15, depending upon experience
Load	Use a load that the adolescent can lift for the desired number of repetitions
Frequency	2–3 nonconsecutive days per week
Exercises	Involve all major muscle groups: chin-ups, bench press, lat pulldown, leg press, leg flexion and extensions, abdominal crunches, biceps and triceps curls, calf raises, stability or ball exercises, rowing

Data from Vaughn J, Micheli L. Strength training recommendations for the young athlete. Phys Med and Rehabil Clin N Am 2008;19(2):235–45; and Miller MG, Michael TJ. Strength training and conditioning. In: Patel DR, Greydanus DE, Baker RJ, editors. Pediatric practice sports medicine. New York: McGraw Hill; 2009. p. 46–55.

of sets is increased, while the number of repetitions per set is decreased. Concurrent with the increase in number of sets and the decrease in repetitions, the duration of rest periods should increase. If the goal of RT is to increase strength, adolescents should begin with one to two sets of 6 to 15 repetitions involving all major muscle groups using lighter loads.[1] If the goal of RT is to increase muscle power, three to six repetitions should be performed because of increased muscle fatigue associated with power exercises.[1]

Although there are individual variations, generally it takes at least 8 or more weeks of consistent exercises before training effects from RT are realized.[1–8] The load, number of sets, and number of repetitions per set can all be altered to accommodate for exercise adaptations and to maintain or gain training effects. The exact methods of determining the amount and timing of load increase are not defined clearly. One simple way suggested is to increase the weight lifted or number of repetitions per set, when the current weight lifted or the number of repetitions can be accomplished with relative ease. One method to judge when to increase the weight or load lifted during an exercise is called the "two for two rule." The weight or load is increased when the adolescent can perform two or more repetitions over the current number of repetitions for that particular exercise over two consecutive exercise sessions.[32]

In general, the load is initially increased keeping the number of sets and repetitions per set the same. How much to increase load may vary depending upon the individual response, capability, and goal of training. If the primary goal is to increase muscle strength, a general guideline to work with is to increase the load by 5% to 10% with a relatively smaller increase for upper body exercises, and a larger increase for lower body exercises.[1,4] For most adolescents, in practical terms, the load or weight lifted can be increased by 1 to 4 kg for upper body exercises and by 4 to 7 kg for lower body exercises.[1,4]

The recommended progression for focused training for power shares some similarities with the progression for focused training for strength. There are some key differences, however, that must be considered. Adolescents training for power should use multijoint exercises rather than single-joint exercises. Like the progression for strength, when training for power, intensity should be increased progressively as experience is gained. Similarly, the number of sets should be increased while the number of repetitions per set decreases. Rest intervals, the velocity of muscle action, and the frequency of training sessions should also increase as the adolescent progresses from the novice to advanced level.

Specificity

Adaptations of muscles to RT are specific to the stimulus applied. This is known as the specific adaptations to imposed demands (SAID) principle.[4] Factors that determine the specific physiologic adaptations resulting from RT include the type of muscle actions involved, the velocity or speed of movement with which a muscle action is performed, range of motion, muscle groups trained, energy system involved, and the intensity and volume of training.[4,5]

Periodization

For long-term RT, different program variables are manipulated to maintain or continue to gain training effects. Variation in RT throughout the training period is called periodization, and is especially important for sports-specific training.[4] Periodization usually is divided into different phases based on the time of year or desired training outcomes to increase performance, minimize overtraining, or decrease the likelihood of training effect plateaus.[5,32] Periodization also may reduce boredom and encourage adolescents to adhere to their resistance training programs throughout the year. Different types of exercises, intensity, duration of rest periods, and overall volume of exercise session are manipulated based upon the RT experience and goal of the adolescent.

Box 1
General guidelines for an adolescent RT program

Establish a training program that is both challenging and exciting for participation

Qualified strength and conditioning professionals such as those certified by the National Strength and Conditioning Association or American College of Sports Medicine should develop training programs for adolescents

A preparticipation screening by qualified physicians or allied health professionals is essential to screen for pre-existing conditions or injuries

If the preparticipation screening detects physical limitations or strength deficits, a comprehensive program to correct these deficiencies should be implemented when beginning a RT program

RT programs for adolescents should emphasize submaximal efforts, using their body weight or bars with no added weights. Improving muscular strength and endurance are preferred goals initially; power exercises are included as the adolescent becomes more experienced

The RT program should focus first on mastery of technique and motor skills using light weights before progressing to heavier resistance training and more complex multijoint exercises

Avoid maximum load lifts. The multiple-repetition maximum method is preferred to determine load

Perform all exercises through the entire range of joint motion and with proper form

Instruct on the proper methods to breathe during exercise and make sure participants do not hold their breath

Have adequate supervision in the facility, including the use of spotters if necessary

Make sure the facility is safe, well-ventilated, and illuminated properly

Resistance training should be performed only 2 to 3 nonconsecutive days a week with adequate rest and recovery between sessions. Each session should comprise a general warm-up period, flexibility, resistance training exercises, and a cool-down period.

Data from Refs.[1,29,32]

SUMMARY

A RT program can benefit adolescents significantly by increasing physical fitness, sports performance, and psychosocial well-being. Any potential risks are minimal and primarily related to inadequate supervision and incorrect training techniques. Therefore, most risks can be alleviated significantly through the use of proper supervision and appropriately designed training programs that emphasize proper techniques. Although differences exist between levels of experience, all participants should follow basic recommended resistance training guidelines (**Box 1**).[1,29] To achieve, maintain, and gain training effects, resistance exercises must be done consistently and regularly over time. It takes several weeks to gain training effects, and the adolescent begins to lose the gains after complete cessation of exercises for 2 weeks. The longer the RT experience, the longer it takes to lose the training effects. RT exercises constitute one component of training and conditioning; other aspects such proper nutrition, rest, and healthy lifestyle choices are equally important. Adolescents must be advised against use of any performance-enhancing drugs or nutritional supplements to gain muscle mass and strength.

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