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Resistance Training for Children and Adolescents

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Resistance training is becoming more important as an integral part of comprehensive sport training regimens, school physical education classes, and after-school fitness programs. The increasing number of youth who are involved in sport activities, coupled with the health problems of inactivity and being overweight, have resulted in increased interest in resistance training. Secular declines in measures of muscular fitness in modern-day youth highlight the need for participation in youth resistance training for nonathletes as well as athletes. Parents often ask pediatricians to offer advice regarding the safety, benefits, and implementation of an effective resistance-training program. This report is a revision of the 2008 American Academy of Pediatrics policy statement and reviews current information and research on the benefits and risks of resistance training for children and adolescents.

KEY POINTS

1. Positive outcomes of improved strength in youth continue to be acknowledged, including improvements in health, fitness, rehabilitation of injuries, injury reduction, and physical literacy.
2. Resistance training is not limited to lifting weights but includes a wide array of body weight movements that can be implemented at young ages to improve declining measures of muscular fitness among children and adolescents.
3. Scientific research supports a wide acceptance that children and adolescents can gain strength with resistance training with low injury rates if the activities are performed with an emphasis on proper technique and are well supervised.
4. Gains in childhood strength are primarily attributed to the neurologic mechanism of increases in motor neuron recruitment, allowing for increases in strength without resultant muscle hypertrophy.

abstract

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5. It is important to incorporate resistance training into physical education classes and youth sport programs to increase muscular strength, reduce the risk of overuse injuries, and spark an ongoing interest in this type of exercise.
6. Certain health situations require consultation with a medical professional before starting a program of resistance training.

BACKGROUND

Resistance training and strength training are synonymous terms used to denote a component of sport and exercise training that is designed to enhance muscular strength, muscular power, and local muscular endurance for general exercise or competitive sports. Resistance training is a specialized method of conditioning that involves the use of different modes of training with a wide range of resistive loads, from body weight to barbells. Resistance-training programs may include the use of free weights (barbells and dumbbells), weight machines, medicine balls, kettlebells, elastic tubing, or a person's own body weight to provide the resistance needed to increase strength.

Along with the extremes of inactivity and/or being overweight and the evolution of youth sports into more intense training at younger ages, there is also a change in the landscape of "strength" among children and adolescents. Evidence of decreasing measures of muscular fitness in youth over the years adds importance for involving youth in some form of resistance exercise regardless of whether they are involved in sports.[1–3] On the other hand, some adolescents are increasingly using resistance training in pursuit of muscularity without even being involved in sports.[4] The type, amount, and frequency of resistance exercises are dictated by the specific and unique goals of the sport and training program as well as the individual child's resistance training skill competency (RTSC) and accumulated time of formal resistance training (also referred to as "training age"). Table 1 defines an alphabetical list of common terms used in resistance training.

RESISTANCE-TRAINING BENEFITS

Performance Benefits

The many benefits of resistance training have been increasingly documented in the pediatric sports arena. Although building strength is often a primary goal, the positive sequelae of strength gains in youth continue to be recognized, including improvements in motor skill performance, gains in speed and power, developing physical literacy, reducing the risk of injury, and injury rehabilitation. Children and youth are entering competitive sports at younger ages, and their training programs are becoming more complex and can involve the use of private coaching, personal trainers, and sports psychologists in addition to their routine coaches and teams. Possessing adequate strength to keep up with these increased demands on the body is valuable to help reduce the risk of injury and optimize gains in performance.

TABLE 1 Definitions

Term	Definition
Bodybuilding	Lifting weights with the specific goal of increasing muscle size, symmetry, and definition with the possible goal of entering competitive events that are judged
Concentric muscle action	The muscle shortens during contraction (ie, lifting phase of bicep curl)
Core strengthening	Focusing a strength-building program on the muscles that stabilize the trunk and pelvis of the body; this training emphasizes strengthening the abdominal, low back, and gluteal muscles as well as flexibility of muscular attachments to the pelvis, such as the quadriceps and hamstring muscles
Eccentric muscle action	The muscle lengthens during contraction (ie, lowering phase of bicep curl)
Integrative neuromuscular training	Multimodal exercise program using different types of resistance training to target deficits in strength and motor control by improving both health- and skill-related components of physical fitness
Isokinetic muscle action	This exercise requires special equipment that maintains a fixed speed of muscle contraction throughout the range of motion
Muscular fitness	A global term that includes muscular strength, muscular power, and local muscular endurance
Physical literacy	Moving with confidence and competence in various activities and environments to benefit overall health
Plyometric exercises	Repeated, rapid, eccentric, and concentric muscle actions, such as side-to-side hops or squat jumps
Powerlifting	A competitive sport that involves maximum lifting ability; powerlifting includes the dead lift, back squat, and bench press
Prehabilitation	Strength, flexibility, and functional training aimed at preventing injuries before they happen or reducing the risk of a recurrent injury
Repetition (rep)	One complete movement of an exercise that typically involves lifting and lowering a load
Repetition maximum (RM)	The maximum amount of weight that can be lifted with proper exercise technique using a given resistance; a 1 RM is the maximum resistance that can be used for 1 complete repetition of an exercise, whereas a 10 RM is the maximum resistance that can be used for 10 complete repetitions of an exercise
Set	A group of repetitions performed continuously
Weightlifting	A sport that involves the performance of the snatch and clean-and-jerk exercises in competition
Weightlifting training	The use of weightlifting exercises, movements, and derivatives of these exercises incorporated into a training program

Health Benefits

Healthy lifestyles incorporate regular exercise that provides a balance of activities, including participating in strength-building programs. In addition to increasing muscular strength, muscular power, and local muscular endurance, resistance training has been shown to produce many health benefits, including improvements in cardiovascular fitness, body composition, bone mineral density, blood lipid profiles, insulin sensitivity in youth who are overweight, increased resistance to injury, and mental health.[5–14]

Programs involving resistance training provide positive options to engage children and adolescents with overweight or obesity in physical activity and may be more likely to create a positive and successful experience for these participants, who may have lower levels of physical fitness, poor exercise compliance, and reduced tolerance for aerobic training.[15–17] Evidence does show that participation in a resistance-training program helps increase daily levels of spontaneous activity in school-aged boys,[18,19] which suggests that resistance training may be a good place to start when trying to get inactive kids to be more active. Progressing into a combined program of resistance and aerobic training may generate added benefit because combined programs have shown favorable effects on the reduction of total body fat in youth.[20–22]

Additional Benefits

After years of research, it is now accepted that children and adolescents can increase strength with low injury rates if resistance training is well supervised with an emphasis on correct technique. Early studies successfully demonstrated significant strength gains in children and a lack of injury with proper technique and supervision.[5,7,12,23]

With a preponderance of studies showing positive gains from youth resistance training, perspectives are shifting regarding integrating resistance training into physical education, youth fitness, and injury-reduction programs.

Previous concerns regarding resistance training focused on what would happen if a child lifts weights, but more recent focus has turned toward what will happen if a child does not lift weights, especially in light of the secular declines in measures of muscular fitness over the years. Targeting strength deficits and building strength reserves will continue to be a valuable concept to address.[24,25] The available research supports resistance training in youth with a new perspective of acquiring and maintaining high strength reserves to enhance performance across a wide range of general and specific skills while reducing injury risk. There is a shift from the primary concern of injuries associated with resistance training to the concern of injury and other adverse events because of a lack of adequate strength to keep up with training demands.[14,26,27]

Resistance training is applicable to virtually all children and adolescents for contributions to muscular fitness, resistance to injury, and improved performance. Enhancing muscular strength is an important concept to embrace fully beyond the association with only lifting progressively heavier weights. This clarification may encourage girls and boys to engage in year-round resistance training to increase their strength reserves without fear of getting too muscular or impairing sports performance.

Numerous studies have shown that children and adolescents can gain strength with resistance-training programs involving technique-driven progression along with qualified supervision and instruction.[5,7,12,23,28–30] Adequate supervision may be variable depending on the goals of the resistance-training program, RTSC of the participants, and experience of the teacher, instructor, or coach. An experienced professional may be able to effectively guide a larger number of youth, whereas more individualized instruction may be appropriate for more advanced-level techniques. There are many different variables that contribute to a well-designed youth resistance-training program, including quality of instruction, training environment, training frequency, training age, type of resistance used, intensity of effort, number of sets and repetitions, rest interval between sets and exercises, and duration of training.[26]

Training and Detraining

Recent studies suggest that resistance-training programs lasting >23 weeks are most effective in attaining maximal strength gains.[30] Strength gains occur with different types of resistance training for a minimum duration of 8 weeks with a frequency of 2 to 3 times a week. In general, detraining effects can occur after 8 to 12 weeks without resistance training,[5,7,11,15,31,32] but detraining is a more complex process in youth because of developmental improvements in performance, which allows some skills to be retained better than others.[32] Children recover more quickly than adults from resistance-training fatigue; therefore, experts recommend 1 minute of rest between sets for beginners, increasing to 2 to 3 minutes of rest as the intensity of training increases (ie, incorporation of weightlifting movements or plyometric exercises).[33] Training exercises involving the core (abdominals, low back, and gluteal muscles) are foundationally important for sports participation and can provide benefit for sport-specific skill acquisition and postural control.[7,34,35]

One-Repetition Maximum

The one-repetition maximum (1 RM) (see Table 1 for definition) test can be administered by qualified professionals to assess maximal strength, determine an appropriate resistance-training intensity, and evaluate the effectiveness of a resistance-training program.[36] Previous American Academy of Pediatrics (AAP) policy statements have not recommended 1 RM testing in skeletally immature individuals. However, 1 RM testing that is properly administered has been found to be a valid and reliable measure of strength and power in children and adolescents.[36,37] Although 1 RM testing is used in pediatric research settings and youth sport facilities, alternative measures (handgrip strength, long jump, and vertical jump) correlate with 1 RM strength and may be used to evaluate muscular fitness in youth.[38] Research indicates that 1 RM testing in children and adolescents can be safe and efficacious when established testing protocols are followed by qualified professionals.[36,37,39,40]

Mechanisms of Strength Gains

Proper resistance training in children can enhance strength without resultant muscle hypertrophy. These strength gains are attributed primarily to a neurologic mechanism whereby training increases the number of motor neurons that are "recruited" to fire with each muscle contraction.[41,42] This mechanism accounts for the increase in strength in populations with low androgen concentrations, including girls and preadolescent boys. In contrast, resistance training during and after puberty augments muscle growth by actual muscle hypertrophy.[11] Early studies regarding resistance training involved nonathletic children, but an increasing number of studies are being conducted with competitive young athletes.[43,44] Further research is needed in the area of long-term strength improvements with resistance training programs in young athletes and the effect on the neurologic mechanism of motor unit recruitment.

Performance Enhancement and Other Uses of Resistance Training

Increases in strength with resistance programs have shown improvement in some performance measures, such as vertical jump, countermovement jumps, and sprint time[6,45–47] as well as improved maximal oxygen uptake with combined resistance and aerobic training programs.[48] Resistance training combined with aerobic training does not appear to impair strength gains in youth and may be more beneficial than single-mode training.[32,49] Translation of those improvements to overall athletic performance on the field or court may be more difficult because so many variables are involved with actual performance, making it challenging to separate the contribution from resistance training alone. However, positive results in the area of performance measures, along with other aspects of sport, such as injury rehabilitation and injury reduction, make resistance training a valuable piece of the training landscape and foundational to long-term athletic development.[50,51]

Prehabilitation

Preventive exercise (prehabilitation) uses resistance training to address and focus on joints that are commonly at risk for overuse injuries (ie, enhancing rotator cuff and scapular stabilization strength preventively to reduce shoulder injury in athletes who are involved in overhead sports, such as baseball, softball, tennis, volleyball, swimming, and water polo). Research in adolescent athletes has shown resistance training to contribute to decreased injuries.[5–7,14,52,53] Injury prevention programs may have greater effectiveness when started before the period of altered biomechanics that increase injury risk.[54–56]

Various prehabilitation studies are finding positive results in the reduction of anterior cruciate ligament injuries, especially when resistance training exercises are combined with plyometric exercises.[5–7,45,52,57] Plyometric training involves the use of rapid concentric and eccentric muscle actions to enhance muscle strength and power in a relatively short amount of time, such as squat jumps. Plyometric exercises may benefit performance[58–60] and reduce the risk of injury. When combined with proprioceptive training (ie, balance exercises), these programs have also been shown to be beneficial in rehabilitation and reduction of certain injuries, such as ankle sprains.[61]

RESISTANCE TRAINING RISKS

Injury rates in youth resistance training settings that adhere to qualified supervision and proper technique are lower than those occurring in other sports or general recess play at school.[4] On the basis of years of research in this area, there is less concern for injury from supervised, well-designed, and technique-driven resistance training and more concern for injuries that occur because of poor supervision, an inappropriate progression of training loads, or low strength reserves in youth who are not prepared for the demands of sports practice and competition.

Overtraining Risks

Resistance training has more of a place in injury reduction than in the cause of injury. However, prolonged training with heavy loads and resistance training without adequate rest and recovery between sessions have been correlated with increased injuries and illness,[62–64] thus requiring similar attention as with other sources of overtraining and

sensible incorporation into the yearly training schedule. It is important to account for time spent in resistance training as part of total training time to reduce the risk of overuse injuries. Resistance training can be incorporated into a year-round plan that varies in volume and intensity depending on the sport season (eg, preseason, in season, or off season).

The AAP recommends rest from competitive athletics, sport-specific training, and practice by taking at least 1 to 2 days off per week to allow for physical and psychological recovery.[65] Adequate fluid and caloric intake is necessary to provide the fuel to exercise, compete, recover, and grow.[66,67] Athletes participating in high levels of training volume who are underrecovered and undernourished are at risk for overtraining, injury, and illness.[68,69]

Skeletal Risks

Appropriately designed resistance training programs have no apparent negative effect on linear growth, physeal health, or the cardiovascular system.[7,22] Explosive contractions of the muscle-tendon attachment at apophyseal areas during active play, sports, or lifting weights may increase the risk of avulsion fracture until closer to skeletal maturity.[70,71] Resistance training safety is enhanced when teachers, coaches, and instructors ensure a safe training environment and use developmentally appropriate teaching strategies, focus on enhancing RTSC, and have an appropriate instructor/participant ratio. This ratio can vary on the basis of the expertise of the instructor, program design, and training age and RTSC of participants.

National Electronic Injury Surveillance System

Results of the US Consumer Product Safety Commission's National Electronic Injury Surveillance System (NEISS) have raised concerns about injuries from the use of weights and resistance training. The NEISS collects data on injuries related to strength training equipment but does not provide information on supervision, program design, or training experience. This system warrants mentioning in this report to reduce conflicting information among the general public who read NEISS information. Careful interpretation of NEISS data is needed because most injuries reported from resistance training occur on home gym equipment with unsafe behavior in unsupervised settings.[72] These data are in stark contrast to data from well-designed studies with appropriate supervision and technique, making education of parents necessary to reduce confusion about the risks associated with resistance training in the youth population.[12,73–75]

NEISS data suggest that muscle strains account for many of the reported injuries, and areas that are most commonly injured are the hand, low back, and upper trunk; recent NEISS data also suggest that hand injuries are particularly common in children <12 years old.[76,77] NEISS data neither specify the cause of the injury (ie, attempting to lift a heavy load with poor technique) nor separate recreational from competitive weightlifting or powerlifting injuries, but the data support the need for qualified supervision and equipment that are appropriate for the size and skill level of youth involved in resistance training.

Various intense metabolic conditioning programs incorporate different types of resistance training, running intervals, and repetitive body weight exercises, such as plyometrics, into training sessions. This type of high-intensity circuit training is typically characterized by the performance of a maximum number of repetitions of selected exercises for a predetermined time interval. In adult metabolic conditioning programs, the shoulder, knee, and low back are most commonly injured,[78] but safety in the pediatric population is undetermined because of a lack of current data. As with any type of resistance training, it is important to have proper exercise technique, qualified supervision, and adequate recovery between intense training sessions.

Medical Conditions

Certain health situations require special attention before beginning a resistance training regimen. Athletes with poorly controlled, preexisting hypertension require consultation with a medical professional because of the risk of marked elevation of blood pressure during resistance training with weights. Using one's own body weight is an acceptable alternative until a consultation can be obtained.[79,80] Consultation with a medical professional regarding resistance training is also required for young athletes with uncontrolled seizure disorders,[81] although resistance training has been determined to be safe in children with underlying seizures that are well controlled on medication.[81,82]

Some children and adolescents may be disqualified from participation in resistance training because of certain medical conditions. Counseling against resistance training is necessary for youngsters with hypertrophic cardiomyopathy who are at risk for worsening ventricular hypertrophy and restrictive cardiomyopathy or hemodynamic decompensation secondary to an acute increase in pulmonary hypertension.[83] Resistance training should be avoided in individuals with pulmonary hypertension because of a risk of acute decompensation during a sudden change in hemodynamics as well as those with Marfan syndrome.[83]

Although exercise interventions that include resistance training may be beneficial for youth with cancer,[84] certain chemotherapeutic agents require caution. Youth with a previous history of cancer treated with anthracycline chemotherapy are at increased risk for cardiotoxicity and acute congestive heart failure during resistance training, as evidenced by case reports associated with doxorubicin, daunomycin or daunorubicin, idarubicin, and possibly mitoxantrone.[85]

Misconceptions and Evidence

The health supervision visit is a good opportunity to explore the topic of resistance training, dispel the myths associated with this type of exercise (Table 2), and discuss the importance of staying physically active and strong. These visits can allow for the identification of risk factors for injury; discussion of family history, medical conditions, medications, previous injuries, as well as training goals; motivation for resistance training; discussion of experience; and discussion of expectations from both the child and parents. It is valuable for pediatricians to counsel families about the multiple health and fitness benefits of resistance training, including improvements in muscular strength, muscular power, sports performance, injury resistance, and long-term athletic development.

Performance-Enhancing Substances

The AAP strongly opposes the use of performance-enhancing substances and vigorously endorses efforts to eliminate their use among children and adolescents.[86] Information is available for health care providers to provide regarding the risks and health consequences of anabolic steroids and other performance-enhancing drugs as well as to discourage youth from considering their use. For instance, the AAP has a training simulation on addressing the use of performance-enhancing substances (available at www.aap.kognito.com).

Integrative Neuromuscular Training

In this era of sedentary pursuits of technology and social media, keeping children and adolescents active and optimally developing motor skills, muscular fitness, and physical literacy is challenging. No longer can it be assumed that children innately know how to run, hop, jump, and throw. Integrative neuromuscular training is a multimodal form of training that uses resistance exercises, dynamic stability, core exercises, and plyometric and agility training performed in short intervals with intermittent periods of rest.[26,87] Integrative neuromuscular training can improve muscular fitness in youth, enhance motor skill development, improve sports performance, and decrease sports injury risk.[12,87]

It is difficult to say at what age a child can begin resistance training because of developmental differences. If a child is able to begin participating in sports activities at 5 years of age, being able to begin some type of resistance training with body weight movements at that age is acceptable because strength gains can be made in ways other than lifting external loads. An age range of 5 to 7 years is when many children are often involved in sports participation, and it is reasonable that they can also benefit from the strength-building process with exercises such as frog jumps, bear crawls, crab walks, kangaroo hops, and one-leg hops.[88] The one-leg hop is a skill most 5-year-olds should be able to perform,[89] although the ability to perform more complex movements will be influenced by the amount of time youth have practiced basic skills and reinforced desired movement patterns. The combination of qualified instruction with technique-driven progression is likely to yield the greatest benefits for youth at any age.

Training Age

The more recent concepts of "training age" and RTSC can be used in the design of a resistance training program. Training age refers to the

TABLE 2 Misconceptions Versus Evidence

Misconceptions	Evidence
A child is unable to increase strength before puberty.	Prepubertal children are able to gain strength by an increase in neurologic recruitment of muscle fibers, and gains in strength can be made with low injury rates if resistance training programs are well supervised with an emphasis on proper technique.
Young boys and girls may get "muscle bound" if they resistance train.	Prepubertal strength gains occur by neurologic mechanisms, and pubertal gains may augment muscle growth by actual muscle hypertrophy enhanced by pubertal hormones.
Resistance training may decrease aerobic performance in youth.	Improvements in aerobic performance have been shown with combined aerobic and resistance training programs, and combined aerobic and resistance programs do not appear to impair strength gains in children.
Resistance training may stunt growth.	Well-designed resistance training programs have not been shown to have a negative effect on physeal (growth plate) health, linear growth, and cardiovascular health in youth.
Children are stronger now than ever before.	There is a need to target strength deficits and build strength reserves due to declining measures of muscular fitness in modern-day youth.
1 RM testing is unsafe for youth.	1 RM testing may be a safe method for assessing muscular strength in youth provided that qualified supervision is present and appropriate testing guidelines are followed.

cumulative amount of time spent in formalized training, and RTSC incorporates the quantity of weight lifted, the quality of the lifting movement, and the emotional maturity of the athlete.[26,90] As the athlete's RTSC advances, higher loads may be used in a technique-driven process, and a gradual progression of incorporating skills requiring higher degrees of technical ability may be included (ie, more advanced weightlifting movements and plyometric exercises).[7] Understanding training age and the importance of RTSC allows for developmentally appropriate, progressive training rather than relying on previous recommendations based solely on chronological age. With earlier participation in well-designed and properly supervised resistance training, a 10-year-old girl may already have 3 years of resistance-training experience versus a 14-year-old boy who is a beginner and has a resistance training age of 0.

Ways and Means of Improving Strength

Gains in strength can be acquired via various types of resistance training methods and equipment, including body weight, free weights, resistance bands, kettlebells, medicine balls, and child-size machines. Most fitness centers use equipment made for adult bodies and greater weight increments, but child-appropriate machines are available in some youth centers across the country. Dumbbells, kettlebells, and medicine balls require good balance control and technique while being small in size, portable, and allowing for sport-specific motions.

The Use of Weightlifting Movements

The competitive sport of weightlifting includes the snatch and the clean-and-jerk exercises, whereas weightlifting movements include derivatives of these exercises. Research has demonstrated that this type of weightlifting training is superior in improving countermovement jumps, horizontal jumps, and 5- and 20-m sprints over traditional resistance training.[47,91] Research has demonstrated that if light loads are used to learn these complex movements, and ongoing quality instruction is available for technique-driven progression, then weightlifting exercises and their derivatives can be incorporated into youth training programs safely.[7] Learning how to perform these multijoint lifts correctly requires considerable time and coaching expertise. Performing these multijoint movements in childhood can help youth gain competence and confidence in performing these skills. If weightlifting movements are going to be incorporated into a youth training program, the following guidelines are to be considered.

- Advance in a gradual fashion, learning the lifts with a wooden dowel then progressing to an unloaded, light barbell and finally to a weighted barbell, focusing on proper form throughout the technique-driven progression. These weightlifting movements can be incorporated into beginner programs but will depend on the goal of the program and quality of instruction available.
- Consider training age and RTSC level, which will vary individually on the basis of cumulative training and level of instruction.
- Perform under the guidance of a professional with requisite coaching certifications, such as a certified strength and conditioning specialist (National Strength and Conditioning Association), accredited strength and conditioning coach (UK Strength and Conditioning Association), or USA weightlifting coach (USA Weightlifting).

Competitive bodybuilding is the application of resistance training principles specifically for the appearance-related purposes of maximizing muscle mass, symmetry, and body definition. Endogenous anabolic hormones are necessary for the increased muscle mass that is the primary goal of bodybuilding. "Late bloomers" are often tempted to try to build muscle mass by increasing the intensity and volume of training; however, there is no substitute for the onset of puberty, and increased training does not hasten the biological clock. Concerns about abnormal eating behaviors, excessive focus on body image, or use of anabolic agents and other performance-enhancing substances warrant careful screening for these behaviors in any adolescent who pursues competitive bodybuilding.

Resistance Training Roadmap

Suggestions for youth who are engaged in a resistance training program are as follows.

- Qualified instructors with appropriate certifications who understand youth resistance-training principles and the physical and psychosocial uniqueness of youth should provide real-time feedback to ensure safe and correct movement development.
- Begin with 1 to 2 sets of 8 to 12 repetitions using a low resistance training intensity (ie, ≤60% 1 RM) as proper technique is developed. A low resistance training intensity allows for the completion of 8 to 12 repetitions of a variety of exercises without undue fatigue.
- As RTSC improves and can be demonstrated consistently, it is reasonable to increase weight in 5% to 10% increments and reduce the number of repetitions.
- The program can be progressed to 2 to 4 sets of 6 to 12 repetitions with a low to moderate training intensity (≤80% 1 RM).
- Young athletes can be introduced to periodic phases of lower

repetition ranges (<6) at a higher training intensity (>80% 1 RM) provided that RTSC is high.[30]

- When performing more complex, multijoint exercises, such as weightlifting, the importance of completing all repetitions with proper technique is vital to achieve proper motor control development. During this type of resistance training, fewer repetitions (eg, 1–3) may be productive to aid in motor control development.
- Include all muscle groups, including core muscles, in a resistance training program.
- Perform the various exercises through the full range of motion with proper technique.
- Perform exercises in a particular sequence during training. In general, work large muscle groups before small muscle groups and complex, multijoint exercises before single-joint exercises.
- Achieving strength gains require sessions to be at least 20 to 30 minutes long and performed 2 to 3 times per week on nonconsecutive days while gradually increasing resistance training intensity and volume as strength and RTSC improve.
- Keep the resistance training stimulus effective and enjoyable by periodically varying the exercises, sets, and repetitions.
- Use dynamic warm-up exercises integrated into the training session followed by cool-down periods with appropriate stretching techniques.
- Youth resistance training programs should be technique driven and consistent with the needs, abilities, and maturity level of the participants.

Guidelines have been proposed by the National Strength and Conditioning Association[5] and the 2014 International Consensus position statement on youth resistance training.[7]

Resistance training is highly encouraged as part of a multifaceted approach to physical literacy, exercise, strength building, fitness, and athletic performance in youth. It is valuable to emphasize that combining aerobic training with resistance training also offers long-term benefits for general health and fitness. Important factors concerning child health are fueling the need for resistance training for all youth. Trends of decreasing muscular fitness in youth and the requirement of strength for competency in movement skill development are important and make it meaningful for families to be aware of the benefits of integrating strength-building activities into a well-rounded exercise program for general physical fitness, sports participation, and lifelong health and wellbeing. It is also important for youth who are involved in resistance training to be able to participate in a safe, supportive, and nonabusive environment. Health care providers, parents, and coaches who are interested in learning more are referred to the US Center for SafeSport (www.safesport.org) and the AAP clinical report on organized sports.[92]

RECOMMENDATIONS

The necessity and appropriateness of a youth resistance training program are determined on the basis of the program goals and RTSC of participants. Proper exercise technique and qualified supervision are necessary for youth resistance-training programs to be safe, effective, and enjoyable. With enthusiastic instruction, constructive feedback, and program variation, resistance training can become a lifetime activity. Recommendations for a youth resistance training program are as follows.

1. Obtain consultation with a medical professional before beginning a resistance training program in youth with uncontrolled hypertension, uncontrolled seizure disorders, specific cardiovascular conditions, or a history of treatment with an anthracycline chemotherapeutic agent.
2. Seek consultation with a pediatric cardiologist for children with complex congenital cardiac diseases for guidance on safety and possible modification of participation.
3. Integrate aerobic and resistance training along with other skill-related fitness components into developmentally appropriate exercise training (ie, integrative neuromuscular training) to create a comprehensive fitness program.
4. In youth with overweight or obesity, start with basic resistance exercises over a more aerobically based program to support and encourage successful physical activity both short- and long-term.
5. Include dynamic warm-up exercises in the training session and cool down with less intense stretching.
6. Encourage participants to have an adequate intake of fluids and proper nutrition because both are important for energy storage, recuperation, and competition. Proper fuel is beneficial for the caloric demands of exercise, performance, recovery, and growth.
7. Assess RTSC and provide real-time feedback on exercise technique to minimize risk and maximize benefit from resistance training. This can be achieved by the following.
    - Exercises should be performed initially with little or no load until RTSC improves and proper technique has been mastered.

- Incremental loads may then be added by using either body weight or other forms of resistance as long as proper form can be maintained.
- In youth with more advanced training age, higher loads and intensities will be necessary to increase muscular strength and power in preparation for sports.[30,43,44]
- 1 RM testing may be appropriate to develop an individualized resistance training program and monitor progress.

8. Address all major muscle groups of the upper and lower body along with the core and include multijoint activities, such as squats and weightlifting exercises, for a comprehensive program for building muscular strength and power. These exercises may be complemented by adding more focused exercises to address sport-specific goals.
9. Sensibly incorporate resistance training and account for time spent in resistance training as part of the total training plan to reduce the risk of overuse injuries. Monitoring time spent resistance training in school- and community-based programs in addition to other types of training is important to account for true total training volume.[93]
10. Evaluate any symptom of illness or sign of injury or overuse from resistance training or sport participation before allowing the exercise program to resume.
11. Incorporate weightlifting exercises and their derivatives into an exercise program under the direction of a qualified professional. Progress from a wooden dowel to an unloaded barbell as RTSC improves.
12. Educate athletes about the risks associated with the use of performance-enhancing substances and/or drugs and anabolic steroids to discourage the use of such substances.
13. Enhance resistance training safety by using professionals who are qualified, trained, and aware of the unique aspects of youth and possess a recognized strength and conditioning certification. Instructor/participant ratio is important and depends on the experience of the instructor as well as the training age and RTSC of participants. Licensed physical education teachers and certified fitness professionals with understanding and experience in training youth may provide safe and effective programs for children and adolescents, and young athletes may receive qualified instruction from their high school coaches or strength and conditioning specialists.[94]
14. Use proper technique and supervision by a qualified professional as necessary safety components in any resistance training program involving children and adolescents.

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ABBREVIATIONS

1 RM: 1-repetition maximum
AAP: American Academy of Pediatrics
NEISS: National Electronic Injury Surveillance System
RTSC: resistance training skill competency

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Resistance Training for Children and Adolescents

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