CME

Strength Training for the Young Athlete

CME EDUCATIONAL OBJECTIVES

1. Identify the concept of strength training in young athletes and provide a historical background on changing attitudes toward this practice over the past several decades.
2. Discuss the proven benefits of strength training in young children and adolescents.
3. List guidelines for safe and effective strength training in children and adolescents.

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Adam is a 13-year-old boy who comes into the office with his mother for his preparticipation physical exam. He mentions that he wants to join the football team this year and is interested in lifting weights so he can be "as big as the other kids." His mother is hesitant to allow this because she has heard

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TABLE.

Definition of Common Terms in Strength Training

Strength training	The use of resistance to muscle contraction to increase one's ability to exert and resist force. Also known as resistance training.
Weight training	Type of strength training that uses the force of gravity (weight) to generate resistance.
Weight lifting	Sport in which participants attempt a maximum weight single lift. The two lifts in competition are the "clean and jerk" and the "snatch." Also called Olympic weight lifting.
Power lifting	Sport in which participants also attempt to lift maximum weights. The lifts performed are the "squat," "bench," and "deadlift."
Body building	Competition in which participants engage in body modification to increase muscle size and definition and are judged on their physique.
Core strength training	Exercise program focused on increasing strength to the muscles of stabilization in the abdomen, hip, and spine.
Calisthenics	Exercises that use one's own body weight to increase strength and flexibility. Generally used in warm-ups. Examples include jumping jacks, sit-ups, push-ups, and lunges.
Plyometrics	Exercises that utilize rapid eccentric and concentric muscle contractions to increase power and speed in performance.
Set	A group of repetitions.
Reps	Abbreviation for repetitions.
One-repetition maximum (1RM)	The maximum amount of weight one can lift in a single repetition for a given exercise.
Rest interval	Period of non-stress activity in between sets or exercises.
Periodization	The modulation of a program in which volume and intensity is changed over time to stimulate gains and allow recovery. One common method is to decrease volume and increase intensity over the course of the training cycle.

that it will adversely affect his growth. The parents want to know if it is safe for him to lift weights and if doing so will help him achieve his goals.

This article is a review of strength training in children and adolescents. Strength training is the use of resistance methods to increase muscular strength and endurance. It utilizes repetitive, submaximal, progressive muscle resistance to accomplish these goals. The purpose of this review is to provide primary care physicians with the most recent knowledge of strength training so that they may better guide and educate the young athlete.

BACKGROUND AND INTRODUCTION

In the past 2 decades, strength training has become an increasingly integral part of many sports and physical fitness programs for young athletes and nonathletes. Strength training in prepubescents and adolescents, however, has not always been widely supported. In 1983, the American Academy of Pediatrics's (AAP) position on strength training was to discourage it in the prepubescent and skeletally immature population. The recommendation was based on the belief that prepubescent children lacked sufficient circulating androgens to produce significant strength increases and that excess loads to the immature skeleton would cause damage to growth plates and premature closure of epiphyses.[1]

Since 1983, studies in the pediatric population have shown that strength training is effective in improving strength and flexibility[2-7] and that it poses minimal injury risk to children and adolescents.[6,8-10] Today, strength training for children and adolescents in a supervised setting, with proper technique and safety precautions, is supported by many national and international organizations[11-16] and is an integral part of many preseason sport conditioning programs.

It is important to make the distinction between strength training and other similar activities. Strength training should not be confused with weight training, weight lifting (also known as Olympic lifting), power lifting, or body building. The AAP is opposed to the participation of children in the sports of weight lifting, power lifting, and body building because of the risk of injury to the immature skeleton and the currently limited data on their safety.[11]

To help better understand the terminology and culture of strength training, definitions of the common terms used in this article is provided in the Table.

BENEFITS OF STRENGTH TRAINING

For pre-adolescents and adolescents, strength training with proper instruction and technique has been shown to increase strength, flexibility, and endurance effectively.[5,17] As opposed to adolescents and young adults who have increased circulating androgens, the strength gains by preadolescents are not associated with muscle hypertrophy. Instead, strength gains seem to be attributed to a neuromuscular mecha-

nism in which there is increased neuronal activation with muscle contractions.[18,19] Increased strength may also be attributed partially to improved motor coordination. It seems that relative strength gains in pre-adolescents are equal to or greater than those achieved by adolescents. In absolute strength gains, adolescents make greater gains than pre-adolescents, and adults make greater gains than adolescents.[15]

For young athletes, one of the major goals of strength training is to improve performance on the field. Whether strength training directly leads to improvement in sport performance, however, is difficult to assess because there are many factors that contribute to, and many outcomes that define, success. Some studies have reported benefits of strength training in handball,[20] soccer,[21] swim performance,[22] and even balance and skate speed in junior ice hockey players.[23] Improvements in specific motor performance skills, such as long jump, vertical jump, and sprint speed, have also been reported.[15] In adults, a program that combines strength training with plyometrics (rapid, eccentric, and concentric muscle contractions) may have synergistic effects on performance,[24,25] and similar benefits are possible in adolescents.[26,27] In general, it is reasonable to assume that strength training in conjunction with a conditioning and plyometrics program can be beneficial to the performance of a young athlete.

The incidence of sport-related injuries is on the rise in children and adolescents because of increased participation in school-sponsored and independently run sports. Part of the reason for the increased incidence of injury is that these athletes may be poorly prepared or improperly trained for such activity.[15] Risk factors that can lead to injury include a history of injury, poor conditioning, muscle imbalances, and training errors. Although there is no definitive evidence that shows strength training directly reduces the prevalence or severity of sport injuries, a complete fitness conditioning program, which includes strength training, can reduce the likelihood of sports-related injuries in young athletes.[28-30] Two studies showed that pre-season conditioning programs that incorporated strength training can decrease the incidence and severity of injury in adolescent athletes in football and soccer.[31,32] Other studies also showed that a conditioning program that incorporates resistance training, plyometrics, and education on jumping mechanics significantly decreased the incidence of serious knee injuries in female athletes.[33,34] Overall, the weight of evidence suggests that a comprehensive conditioning program that includes strength training can increase strength, flexibility, and joint stability and will contribute to reduced risk of injury.

The benefits of strength training can also be seen in improvements to overall health. Similar to other forms of physical activity, strength training has been shown to improve body composition, cardiovascular fitness, bone mineral density, and mental health.[2,35,36] Studies have reported improvements of blood lipid profile in children and adolescents. It may also be an effective method in reducing blood pressure in hypertensive youth.[36] The benefits to bone health are demonstrated in increases to bone mineral density, bone mineral content, and bone mineral density in prepubertal boys and girls, pre-menarcheal girls, and adolescents.[35,36] These changes are because of increased osteogenic activity from weight-bearing exercise and are similarly seen in other sports, such as soccer and gymnastics.

BENEFITS FOR THE OBESE AND OVERWEIGHT YOUTH

Obesity in children and adolescents has risen dramatically in the United States and worldwide.[37,38] Between 1980 to 2002, the prevalence of overweight children and adolescents between 6 and 19 years in the United States tripled. A recent study of obesity in the United States estimated that 16.5% of children between the 6 and 19 years are overweight, and 17.1% are obese.[31] Because of its comorbidities, and the fact that it is likely to persist into adulthood, childhood obesity is a serious public health threat. In the past, strategies to combat obesity have focused on dietary changes and increasing aerobic exercise. Recent studies on strength training in obese children and adolescents also have shown a range of potential health benefits.[39,40]

A strength training program, in conjunction with diet modification or aerobic exercise, has shown to improve body composition, with increased lean body mass and decreased central adiposity in obese and overweight prepubertal children and adolescents.[10,41-43] The increase in lean muscle mass increases basal metabolic rate, thereby assisting in negative energy expenditure and further improvements in body composition.[40]

Similar to other studies in children and adolescents, strength training also produces significant increases in total bone mineral content[10] and better self-perception of strength, endurance, and body composition in obese and overweight children.[44]

For comorbidities associated with obesity, non-insulin-dependent diabetes, and cardiovascular disease, strength training may also have potential benefits. Exercise training can improve glycemic control by decreasing central adiposity and increasing skeletal muscle mass (the most abundant insulin-sensitive tissue in the body and which aids in the clearance of glucose).[45] Improvements in serum triglyceride and insulin levels and percent body fat are also seen.[46] One study even showed that exercise training improved vascular endothelial function in obese children at risk for atherosclerotic disease.[43] Unfortunately, the gains in these studies were also noted to be lost soon after training was discontinued.

In additional to these health benefits, strength training has the potential to be better tolerated by obese youth because of its "circuit" format. It is characterized by short periods of physical activity interspersed with brief rest periods between sets and exercise. This has been observed

to be more typical of how children move and play.[47,48] One word of caution is that overweight and obese children and adolescents may look stronger and more physically mature than they actually are. Parents, trainers, and coaches should be aware that these youths require the same precautions in assessing readiness for initiation and progression in a strength training program as youth who are not obese.

CONCERNS IN STRENGTH TRAINING

The safety of strength training for children and adolescents is a long-standing concern that has largely proved to be unfounded. In the 1970s and 1980s, much of the concern stemmed from reports by the National Electronic Injury Surveillance System (NEISSM) of the U.S. Consumer Product Safety Commission (CPSC), which in 1979 reported 17,000 injuries related to weight lifting requiring emergency room visits by young people 10 to 19 years. In 2008, the NEISSM estimated 24,094 injuries in the United States because of weight lifting activity and equipment.[49] The severity of these injuries ranged from strains and sprains most commonly to fractures less frequently. Unfortunately, the situations in which these injuries occurred are not recorded, making them hard to interpret.

A 2006 review of 10 strength training studies concluded that programs with supervision and low instructor-to-participant ratios were relatively safe.[8] Compared with injuries from other sports, injuries rates secondary to lifting weights were lower.[8] One study reported weight lifting injury rates at 0.7% compared with football and basketball, which were 18.9% and 15.1%, respectively.[10] Strains are the most common injury, with the most common injured location being the lower back.[8,10] Although there are case studies that have reported growth plate injuries, they are rare and usually associated with improper technique and unsupervised activity, and no such injuries have been reported in prospective strength training studies.[8]

Although generally safe, there are specific issues for which strength training is contraindicated, and others for which special precautions should be made. The 2008 AAP Policy Statement on Strength Training in Children and Adolescents recommend that youth with Marfan syndrome, cardiomyopathy (especially hypertrophic cardiomyopathy and those at risk for worsening ventricular hypertrophy and restrictive cardiomyopathy), and those with pulmonary hypertension should refrain from strenuous weight training. Those with a history of cardiotoxic chemotherapy, such as anthracyclines, should be approached with caution. Those with a seizure disorder should be withheld from strength training programs until clearance by a physician.[11]

GUIDELINES FOR YOUNG ATHLETES

Assessment of Readiness

There is no recommended minimum age requirement for initiating strength training in children. In general, children who are ready to participate in organized sports are also physically and mentally able to participate in a strength training program. This is generally around 7 or 8 years, although children as young as 5 years have been reported to participate in strength training.[15] Each child should be assessed individually for readiness. For apparently healthy children, a medical examination is not mandatory, but it can be useful in identifying risk factors and injury history, and it can allow the physician an opportunity to provide proper anticipatory guidance regarding safety and injury prevention. A medical examination is recommended for children with known or suspected disease that may exclude participation or require additional precautions before initiation.

Pre-participation Instruction

The personal goals of the young athlete should be discussed before initiating a program. Realistic goals and objectives should be reviewed. Strength training is a small facet of overall physical fitness, and it should be utilized as a complement to a comprehensive exercise program. It is important is emphasize to parents and athletes that strength training should be fun, safe, and age-appropriate.

Overall, in the United States, there are increasingly more strength training programs offered that are tailored to children of various ages. Choosing a trainer and a training program may be a difficult task, depending on the level of interest in youth sports in your community. Parents and athletes should choose an instructor with experience in youth issues and a program that is age- and goal-appropriate. The NSCA recommends that strength training instructors meet certain qualifications. They should have practical experience working with children and adolescents, a recognized professional certification, and a level of knowledge commensurate with a college degree in physical education, exercise science, or a related field.[15] Professional certification is offered by various organizations, and a list compiled by the AAP 2008 statement offers guidance in understanding the qualifications for available certifications.[11]

Before initiation, all participants should be educated on weight room etiquette, age-appropriate exercise equipment, proper exercise technique, and individual goals and outcomes in order to provide a safe environment. Instruction on safety should include correct use of collars, appropriate spotting techniques, proper handing of barbells, dumbbells, and plates, and proper storage and cleaning of exercise equipment.[15] Injury in the weight room has been attributable to many factors, including improper use of equipment, inaccurate technique, and inappropriate behavior in the weight room. Machines with loads and levers that are created for adults may not be appropriate and can cause harm to children and adolescents. To prevent injury, athletes should be taught on appropriate equipment and begin training initially at low weights. Emphasis should be on cor-

rect technique (controlled movements and proper breathing) and lifting form, not on lifting maximum loads. Proper guidance from a trained professional should be sought before using any equipment.

THE STRENGTH TRAINING PROGRAM

Strength training techniques can utilize varied forms of resistance, such as resistance bands, weight machines, free weights, and even the athlete's own body weight, all of which have been shown to be safe and effective in children under proper supervision. To optimize gains in strength and power, a well-structured strength training program should be performed in conjunction with a progressive conditioning program. which varies the volume and intensity of training throughout the year. There are many ways to design a strength training program, but certain principles should be kept in mind.

All sessions should start and end with a warm-up and cool-down period. A warm-up period of 5 to 10 minutes, consisting of dynamic activity that utilizes the upper and lower body, can help elevate core body temperature and improve blood flow. Dynamic movements, such as running, jumping, and skipping, may be better than static stretching in the warm-up period and were reported to be more effective in enhancing performance.[49,50] A similar 10- to 15-minute cool-down period utilizing calisthenics and static stretching is recommended after training to promote recovery and flexibility.

Exercises should include all major muscle groups and core muscles. Effort should be made to maintain muscle balance across joints and between opposing muscle groups. Exercises should include core strengthening and lower back exercises to prevent injury. In general, large muscle group exercises should be performed before smaller muscle group exercises, and multi-joint exercises should be performed before single-joint exercises. The more challenging exercises should be performed earlier in the workout when the neuromuscular system is less strained so that correct technique is not compromised by fatigue.[15]

Low resistances should be used until proper technique is perfected before adding additional weight. For each exercise, the athlete should perform one to three sets of six to 15 repetitions for each muscle group. Resistance can be added with increases of 5% to 10% increment in weight when eight to 15 repetitions can be performed easily. Performing one maximum repetition (1RM) lifts should be discouraged in children. This measurement of strength is used in power-lifting and can potentially cause injury to the growth plates. Although, there are limited data that suggest 1RM lifts may be safe in children,[51] 1RM lifts are discouraged by the AAP for children and adolescents with open epiphyses.[11]

A period of rest between sets and exercise is recommended to optimize training. In general, the rest interval in between sets and exercises should be 1 to 3 minutes. Recommended rest intervals for adults is 2 to 3 minutes, but some studies suggest that children have a higher threshold of fatigue and can benefit from shorter periods of rest. Therefore, 1RM intervals may be sufficient in younger children, although older adolescents are likely to fatigue closer to the rate of adults and may require longer periods of rest. The length of the rest interval between sets and exercises is important because power production and force can be compromised with insufficient rest.[15]

Training two to three times a week on non-consecutive days will help optimize and maintain gains. Training two to three times per week on nonconsecutive days allows time to recover in between workouts. It has been shown to be most effective in producing gains in strength.[4] To maintain strength gains, training one day per week may be enough, but other studies found that continued training at least 2 days per week is required.[2]

The training program that is varied periodically will optimize long-term performance goals and decrease the risk of overuse injuries. This concept of periodization is a long-term plan that varies training intensity, volume, rest interval, and exercise choice throughout the year. It should also include periods of active rest in which athletes engage in low-intensity exercise to recover between sport seasons, to promote physical and psychological recovery.[15]

PERFORMANCE ENHANCING DRUGS AND STRENGTH TRAINING

Performance enhancing drugs (PEDs) refer to a large group of pharmaceutical drugs and supplements used by athletes to boost performance. They include stimulants, anabolic steroids, growth hormone, protein supplements and amino acids, and blood doping. Such substances are used by athletes to get bigger and faster and to improve their appearance and performance in sports. Unfortunately, many young athletes who use PEDs are unaware of the serious consequences, both to their health and to their eligibility to participate in organized sports. This issue is of growing importance, and recent studies highlight the fact that children are being exposed to and using PEDs at a younger age. The 2005 Middle School Youth Risk Behavior Survey reported that across states, as many as 4.4% of sixth-grade and 4.8% of eighth-grade students had used steroids at least once in their lifetime.[52] Another study in 1998 reported that 2.7% children 9 to 13 years had used anabolic steroids.[53] In adolescents, studies reported that between 4% to 12% of boys and 0.5% to 2.9% of girls have tried anabolic steroids. Data suggest that adolescents who use anabolic steroids are most likely to engage in strength training.[54] These statistics, however, are gathered via questionnaire and not by drug testing, so the true prevalence of anabolic steroid use among children and adolescents is not known.

Another PED of importance is the protein supplement creatine. Creatine is generally viewed as safe in adults, but no studies have been performed in children. It can potentially cause renal failure if taken in excess, especially in those with underlying renal disease. Surveys found its use in high school athletes ranging from 5.7% to 16.7%, with as many as 44% of high school seniors having used creatine.[55-57]

Stimulants, such as caffeine, ephedrine, pseudoephedrine, amphetamines, and methamphetamines, may be even more popular than creatine among high school athletes. Athletes use stimulants to boost their energy level or to lose weight. They are readily available in many easy-to-purchase products, such as energy drinks and cold medications, as well as prescription medications, such as Ritalin. The National Collegiate Athletic Association (NCAA) in 2001 reported that more than 60% of its athletes had tried ephedrine before college, and one study in 2002 reported 26% of high school girls and 12% of high school boys had tried ephedrine products.[58]

The presence of PED use and its dangers in young athletes are real. It is also reasonable to assume that athletes interested in strength training and participating in competitive sport will be tempted by its potential benefits. It is, therefore, important for physicians, coaches, trainers, and parents to be knowledgeable about this issue and to discuss it with their young athletes. Although it is beyond the scope of this review to discuss in detail the specific drugs and their effects, there are a number of recent excellent reviews on PEDs.[55,58]

THE ROLE OF THE PEDIATRICIAN

A pediatrician who is knowledgeable about exercise and strength training can be a valuable resource for the parent and young athlete. For all children and adolescents, pediatricians should encourage at least 60 minutes of moderate to vigorous physical activity daily, as recommended by a Center for Disease Control and Prevention (CDC) expert panel on youth health.[52] For those who express an interest in organized sports and formal training, the pediatrician can assess for readiness to participate and perform the pre-participation exam if necessary, to identify limitations or contraindications to participation. Pediatricians should provide education regarding the importance of nutrition, hydration, and sleep in optimizing training and supporting physical and mental health. They can also provide anticipatory guidance about the dangers of performance enhancing drugs. The informed pediatrician can also be an important resource to the community for coaches and schools regarding safety, first aid, and injury assessment and prevention.

CONCLUSION

Strength training has been shown to be effective in promoting general health and fitness, decreasing risk of injury, and potentially improving sport performance. It should be encouraged by pediatricians for all eligible young athletes as part of a complete fitness program.

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