

# Strength Training for Children and Adolescents

## What Can Physicians Recommend?

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THE PHYSICIAN AND SPORTSMEDICINE - VOL 31 - NO. 9 - SEPTEMBER 2003

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**In Brief:** Primary care physicians who see young patients are often asked about strength training programs for children. Some parents are seeking ways to give their child a competitive edge in sports. Many parents of overweight children seek guidance about which activities are effective for weight loss. Musculoskeletal injuries and epiphyseal fractures are also a concern. Informed clinicians can reassure parents that, with adult supervision, proper equipment, and realistic expectations, strength training programs designed for children and adolescents are safe and effective.

**M**uscle strength development in children has been a topic of debate in the past few decades. However, scientific evidence to separate fact from fiction has been lacking. Youth sports have become more popular and, in many ways, more competitive. Many young athletes and parents are seeking ways to achieve a competitive edge. They are bombarded with confusing and, very often, conflicting information regarding the safety and efficacy of youth strength training. Parents frequently ask if their child will develop big muscles, if athletic performance will improve, if training is safe, or if growth plate injury or stunted growth are possible side effects. Well-informed physicians can help demystify some of the confusion and controversy (see the Patient Adviser "[Choosing a Strength Training Program for Kids](#)").

Understanding the distinctions between strength training (weight training or resistance training) and the competitive sports of weight lifting, power lifting, and bodybuilding is essential.

**Strength training** uses resistance methods to increase one's ability to exert or resist force. Free weights, the individual's own body weight, machines, or other devices (eg, elastic bands, medicine balls) provide resistance.

**Weight lifting and power lifting** are competitive sports that contest maximum lifting

ability. The sport of weight lifting is composed of two competitive lifts: the clean-and-jerk and the snatch. Power lifting involves three competitive lifts: the squat, bench press, and dead lift. Athletes train for these sports at very high intensities.

**Bodybuilding** is an esthetic sport that does not involve competitive lifts but depends on weight training.

Many potentially serious injuries reported in the literature are associated with the sports of weight lifting and power lifting (table 1) and not with competently supervised strength training programs.

**TABLE 1. Weight Lifting– and Power Lifting– Related Injuries and Acute Events**

**Muscle and Tendon Ruptures**

Bilateral quadriceps muscle/tendon rupture  
Distal biceps brachii tendon avulsion  
Patellar tendon rupture  
Pectoralis major muscle rupture  
Pectoralis major tendon avulsion  
Triceps tendon avulsion with radial neuropathy

**Acute Fractures and Dislocations**

Lunate dislocation  
Second rib fracture associated with bench press  
Talar dome fracture associated with squatting

**Acute Medical Events**

Aortic dissection  
Death  
Effort thrombosis  
External iliac artery stenosis  
Myocardial infarction  
Pulmonary embolism  
Spontaneous pneumothorax  
Stroke  
Subarachnoid hemorrhage  
Tetraplegia

Reprinted from Reeves RK, Laskowski ER, Smith J: [Weight training injuries: part 1, diagnosing and managing acute conditions](#). Phys Sportsmed 1998;26(2):79.

**How Much? How Soon?**

The development of muscle strength in children is related to age, body size, previous levels of physical activity, and various phases of growth. The American Academy of Pediatrics (AAP) and the American Orthopaedic Society for Sports Medicine (AOSSM) recommend that, until good data become available to demonstrate safety, children and adolescents

should avoid weight lifting, power lifting, and bodybuilding until they have reached Tanner stage 5 (near physical maturity). These activities show an increased risk of musculoskeletal injuries and potentially dangerous acute medical events for younger participants.<sup>1,2</sup>

In contrast, a retrospective review<sup>3</sup> of injuries associated with weight lifting and weight training in preadolescents and adolescents found that weight lifting and weight training are safer than many other sports and activities. In fact, the rate of injury for weight lifting was even lower than for weight training. The explanation for these findings may be that, to perform the more complex multijoint lifts involved in weight lifting, one must undergo a gradual progression of training loads while learning the technique and mastering the maneuvers. First, a child or adolescent must successfully master the introductory exercises using submaximal loads. Weights are added only under strict, qualified supervision, such as a certified strength and conditioning specialist or a US Weight Lifting Federation Club coach.<sup>4,5</sup>

Based on a study by Hamill,<sup>3</sup> the National Strength and Conditioning Association (NSCA) supports the sports of weight lifting and power lifting as well as strength training in both children and adolescents.<sup>5</sup> A recent article by Faigenbaum and Polakowski<sup>6</sup> also supports weight lifting by children and adolescents, stating that the highly technical maneuvers and lifting techniques make it almost impossible to use too much weight too soon. Emphasis again is on the vital importance of qualified supervision to limit risk of injury.

Admittedly, the confusion over safety in the sports of weight lifting and power lifting will continue as many organizations remain cautious, because research and data on children are limited. For strength training, a plethora of good data exists supporting the multiplicity of health-related benefits that occur as a result of participation in a well-organized and supervised strength training program. Evidence also suggests that a preseason strength training program can reduce sports-related injuries in adolescents.<sup>7,8</sup>

## **Early Studies Cast Doubt**

A 1978 landmark study by Vrijens<sup>9</sup> reported the results of an 8-week resistance training program done three times per week by boys. The preadolescents were incapable of increasing strength or the muscle cross-sectional area of the extremities; however, the adolescents increased strength in all muscle groups tested. A decade later, Docherty et al<sup>10</sup> reported that 12-year-old boys did not benefit from three sessions per week in a 4- to 6-week strength training program that followed their competitive season. However, both studies involved low resistance with only one or two sets of exercises per session, which may not have produced measurable results.

Because of such reports, the ineffectiveness of youth strength training became dogma. The AAP echoed this sentiment in its 1983 policy statement, which stated that "prepubertal boys (pubic hair stage 1 or 2) do not significantly improve strength or increase muscle mass in a weight training program because of insufficient circulating androgens."<sup>11</sup> Thus, resistance training in prepubescents was deemed fruitless and nonessential.

Meta-analyses<sup>12,13</sup> of strength training in children indicate that many studies are flawed by poor methodology. Children continue to grow as they progress through adolescence and subsequently demonstrate natural increases in strength. Therefore, any research to examine

strength gains in a child must incorporate an adequate control to account for natural growth. In addition, the design of the training program (frequency, duration, and intensity of training) is extremely important. As in the studies previously cited, low-intensity training volume (sets x repetitions x load) and short-duration study protocols probably led to inherently flawed results.

## **Increasing Strength**

Today, more reliable methods of testing strength<sup>14,15</sup> and a better understanding of the physiology behind neuromuscular strength are known. Children as young as age 6 can improve strength when following age-specific resistance training guidelines.<sup>16</sup> Two decades ago, initial increases in strength in adult subjects were attributed to neural factors rather than muscle hypertrophy resulting from strength training.<sup>17</sup> Researchers<sup>18</sup> concluded that strength gains seen in resistance-trained children are due to various neural adaptations; actual muscle size is not increased in the prepubertal child.

Two studies<sup>19,20</sup> used the twitch interpolation technique described by Belanger and McComas<sup>21</sup> to assess the contribution of changes in motor unit activation to training-induced strength increases in prepubertal boys. After 10 weeks of training, the motor unit activation of the elbow flexors and knee extensors increased by 9% and 12%, respectively. These studies and many other published reports<sup>2,18-20,22,23</sup> provide compelling evidence that resistance training, when appropriately supervised, can produce substantial increases in muscle strength (but not muscle size) in preadolescents. Increases in neuronal activation, intrinsic muscular adaptations, and improvements in motor coordination (learning) all seem to play a role in strength development in childhood. Faigenbaum et al<sup>24</sup> demonstrated strength gains in prepubertal children with as little as twice-a-week training sessions.

In 2001, the AAP revised its policy statement<sup>25</sup> to reflect the latest research findings regarding strength training by children and adolescents. It now states, "Studies have shown that strength training, when properly structured with regard to frequency, mode (type of lifting), intensity, and duration of program, can increase strength in preadolescents and adolescents." Therefore, parents can be reassured that when their children participate in a strength training program, the children will benefit from increased strength because of their efforts. However, parents will not see an increase in the size of their children's muscles, even though the kids are physically stronger, until after they have reached puberty.

## **Increasing Athletic Performance**

Unfortunately, no long-term studies exist on the effects of preseason resistance training on improved sports performance in children. Anecdotal reports suggest that resistance training enhances athletic performance, but scientific evaluations are limited and the data are conflicting.<sup>4,18</sup> If stretching exercises are a regular component of the strength training program, flexibility has been shown to improve.<sup>4,5</sup> Greater flexibility may add to overall motor fitness and improved sports performance.

The American College of Sports Medicine (ACSM) has stated that properly designed and competently supervised strength training programs may enhance motor fitness skills (eg, jumping, sprinting) and sports performance.<sup>22</sup>

## Maintaining the Edge

Detraining is the temporary or permanent reduction or withdrawal of a training stimulus that may result in the loss of physiologic and anatomic adaptations and a decrease in athletic performance. Small decreases in isometric strength (see "[Definitions for Working Muscles](#)," below) in preadolescent boys were observed after 9 weeks of detraining.<sup>26</sup> Likewise, Faigenbaum and his colleagues<sup>4,27</sup> also demonstrated rapid and significant decreases in upper- and lower-body strength of preadolescents who trained for 8 weeks and were reevaluated 8 weeks after training ceased. In addition, participation in sports such as football, basketball, and soccer did not maintain the training-induced strength gains that were developed during the resistance-training program.<sup>27</sup> The tendency for reduced strength during detraining suggests that training-induced changes that exceed the natural growth-related strength increases are impermanent. Thus, maintenance programs for children are necessary to sustain the strength gains achieved via resistance training programs. The amount of training required, however, needs further research.

## Self-Esteem and Weight-Loss Benefits

Improvement in self-esteem is an important and often overlooked benefit of strength training programs. Some studies<sup>4,5,16</sup> have reported that parents observed positive personality effects in their children, including increased readiness to perform household chores and homework. Data are limited, and a few reports show no significant changes in self-concept, suggesting that the psychological benefits of resistance training depend on the intensity and duration of training. One study<sup>5</sup> noted that the most apparent changes occurred in children who began training with below-average measures of strength and psychosocial well-being.

In an age when childhood obesity statistics continue to increase along with the concomitant risk of developing related diseases such as diabetes and hypertension, children should be encouraged to establish healthy lifestyles at an early age. Strength training may have a cholesterol-lowering effect. Weltman et al<sup>28</sup> reported that a moderate-load resistance-training program with a high number of repetitions had a favorable effect on the blood lipid profiles of prepubescent children. Resistance training combined with aerobic exercise may be the ideal solution for fat loss and weight maintenance in overweight children.

Some literature<sup>4,5,29</sup> suggests that strength training prepares children for participation in organized sporting and recreational activities and improves their sense of character, self-esteem, and overall psychosocial functioning. On the other hand, excessive pressure and unhealthy competition can have emotionally and psychologically adverse effects on children. Youth resistance training programs are safe and effective only if athletes are psychologically mature enough to understand the process, goals, and limitations of the program. Young athletes not ready to participate in organized sports should still be encouraged to participate in free-play activities. This allows the youngster an opportunity to have fun while introducing the body to the stresses of training. In addition, appropriate supervision of a specialized program tailored to the individual athlete on the basis of size, age, sport, and level of experience are essential to maintaining success with minimal risk to the athlete, both physically and psychologically.<sup>2,4,24,25,29</sup>

## Weighing Injury Concerns

Despite the belief that strength training was dangerous or ineffective for children, the safety and effectiveness of youth strength training are now well documented.<sup>12,13</sup> Much of the fear surrounding youth strength training was a consequence of publications such as the National Electronic Injury Surveillance System of the US Consumer Product Safety Commission.<sup>4,5</sup> For example, from 1991 to 1996, an estimated 20,940 to 26,120 weight lifting injuries incurred by children (ages 0 to 21) required emergency treatment each year. The injuries varied in severity from strains and sprains (most common) to fractures (least common); muscle strains accounted for almost 70% of reports. These injury data do not distinguish between properly supervised programs and unsupervised at-home activities, which often lead to excessive loading and improper technique.<sup>4</sup>

Several prospective studies<sup>2,5,22,25</sup> examined the risk of injury to prepubescent strength training subjects under various protocols. The risk of injury was actually very low when children received appropriate supervision. Thus, major health organizations, such as the ACSM, AAP, AOSSM, and NSCA, now support children's participation in appropriately designed and competently supervised strength training programs.

One theoretical concern is that the growing bones of children may be less resilient to physical stresses than the bones of adults. Although a few case study reports<sup>5,14</sup> have noted growth plate fractures in children who lifted weights, most of these injuries occurred as a result of improper training, excessive loading, and lack of qualified adult supervision. A literature review<sup>5</sup> reported no cases of any overt clinical injuries, including epiphyseal fractures, among those in appropriately supervised strength training programs. The risk of an epiphyseal plate fracture in prepubescents is actually less than in adolescents, because the epiphyseal plates are stronger and more resistant to shearing forces.<sup>4,5,14</sup>

Overuse injuries can occur in any repetitive activity, including strength training. A well-designed, properly supervised program aimed at increasing both strength and flexibility may be the best prevention. Prospective studies<sup>2,4,5,23</sup> have demonstrated that prepubertal children can undertake well-supervised strength training programs without incurring clinically evident skeletal injury. A bone scan study by Rians et al<sup>30</sup> showed no evidence of skeletal injury after 14 weeks of concentric strength training.

Low-back injury, however, continues to be the greatest clinical concern, especially in weight lifters and power lifters. Individuals involved in strength training are at risk for both lumbar flexion- and torsion-related injuries (eg, forward displacement of one vertebral body over another that leads to spondylolisthesis, herniated intervertebral disk, paraspinous muscle strain) and lumbar extension-related injuries (eg, facet syndrome, pars interarticularis stress fracture, spondylolysis). However, no evidence about the incidence and severity of musculoskeletal injuries proves that strength training is riskier than simply participating in youth sporting and recreational activities. Shoulder overuse injuries from improper lifting technique and "curler's elbow" are also areas of potential clinical concern in unsupervised and overzealous athletes.<sup>2,5,23,25</sup>

The higher incidence of back and shoulder injuries, especially in beginners, has been attributed to weakness in the abdominal wall, trunk, and shoulder abductor muscles. Therefore, focusing on increasing the strength of the abdominal muscles and intrinsic shoulder muscles and increasing scapular stabilization may reduce the risk of these injuries.

## Effects on Growth

Most of the scientific literature on injury refers to activities other than strength training, such as competitive weight lifting, and to age-groups other than prepubescents. Stunted growth in Japanese children who habitually carried heavy loads on their shoulders was compared with the effects of weight training.<sup>4</sup> The study did not address other factors, such as poor nutrition, sleep deprivation, and general health conditions, all of which may affect growth.

Recent literature<sup>4,5,14</sup> indicates that strength training will not have an adverse effect on growth. A few studies<sup>4,5</sup> have shown positive growth effects as long as proper nutrition and age-specific physical activity guidelines were met. However, resistance training will not affect an individual's genotypic maximum.<sup>4,5</sup> Parents can be assured that strength training (in moderation) will not have an adverse effect on growth. Training may actually be an effective stimulus for growth and bone mineralization in children, especially for those at risk for osteopenia or osteoporosis.<sup>25</sup>

## Beginning Safely

To design and administer a strength training program appropriate for young children, it is imperative to understand that the unique physical and psychological nature of children differs tremendously between individuals at this stage of development. Children must be mentally and emotionally mature enough to follow directions, and this typically occurs when a child is ready to participate in organized sports.

Body-weight exercises, (eg, push-ups, sit-ups) are great for beginners. "Prehabilitation" of the abdominal and shoulder muscles should be implemented to reduce the likelihood of back and shoulder overuse injuries when the strength training program begins.<sup>23</sup> The ability to perform sport-specific plyometric exercises, such as rebounding and long jumping, may be a marker of readiness to engage in formal weight training exercises. For those ready to start using weights, proper form and technique should be emphasized throughout the program. A focus on safe training and individual self-improvement, rather than competition, is key.

Guidelines for strength training have been developed by the AAP, ACSM, AOSSM, and NSCA to promote a safe and worthwhile activity for children (table 2).<sup>2,5,22,25</sup> Equipment specifically designed for use by children is recommended to prevent injury.<sup>4</sup> To prevent increased risk of potentially serious or even fatal injury, an appropriately designed and competently supervised strength training program for children must be safe.<sup>4,15</sup> Good programs can enhance strength, flexibility, motor fitness skills, sports performance, and overall health. Parents may also notice improved psychosocial well-being in their children and fewer injuries in youth sports and recreational activities.

**TABLE 2. Youth Strength Training Guidelines**

### Basic Concepts

- Strength training is one part of a well-balanced youth fitness program
- Training takes place at least 2-3 times per week with a minimum of 1 day of rest

between sessions

- Training involves all major muscle groups, with a balance between opposing muscle groups
- Resistance exercises are done through a full range of motion to develop strength while maintaining flexibility
- Participants are encouraged to maximize their athletic potential by optimizing their dietary intake (ie, adequate hydration, proper food choices)

### **Prehabilitation of the Shoulder and Torso Muscles**

- Begin with minimal resistance (body weight against gravity or a bar without added weights); add weights in 1-lb increments as needed
- Work intrinsic shoulder muscles, with special focus on the anterior deltoid, supraspinatus, middle deltoid, posterior deltoid, internal rotators, and external rotators
- Work upper back (scapular stabilizing muscles) with resistance exercises, including shoulder shrugs, bent-over lateral raises, bent-over rows, bench rows, seated rows, and latissimus pull-downs
- Work lower back and abdomen with resistance exercises, including lumbar paraspinous stretching, 3-direction crunch sit-ups (for rectus and oblique abdominals), and reverse sit-ups (for the lumbar paraspinous muscles)

### **Basic Guidelines**

- Include adequate warm-up and cooldown stretching in every session
- Begin with 1 light set of 10-15 repetitions of 6-8 different exercises
- Encourage success by choosing the appropriate exercises and workload for each child
- Focus on participation and proper technique rather than the amount of weight lifted
- Perform 1-3 sets of a variety of single- and multiple-joint exercises, depending on time, goals, and needs
- When necessary, adult spotters should assist the child in the event of a failed repetition
- Teach students how to use workout cards and regularly monitor progress
- Vary the strength-training program over time to optimize training and prevent boredom

### **When Proper Technique Is Mastered, Weight Can Be Added**

- If a child cannot do at least 10 repetitions per set with a given weight, the weight is too heavy and should be reduced
- When 15 repetitions become too easy, the next weight increment can be attempted (typically a 5% to 10% increase on average is recommended)
- A child should be able to do 3 sets of 15 repetitions of a given exercise in 3 consecutive sessions before more weight is attempted

The minimum requirements for a well-run program include supervision at all times provided by trained and qualified adults, appropriate clothing and footwear worn by all participants, and a child-friendly environment that is safe and free of hazards. Realistic goals should be established based on each child's abilities, needs, and expectations. A 10-minute warm-up of light aerobic exercise and stretching should be done before each session, and at least 10 to 15 minutes of stretching to cool down should follow.

## **Lifting Off**

Strength training in prepubertal children can be a safe and effective way to improve muscle strength and joint flexibility while potentially decreasing the rate of sports-related injury. A properly designed and supervised program can help improve children's overall health and sense of psychosocial well-being. Current published literature demonstrates that the benefits of strength training far outweigh the potential risks. When a child or adolescent is involved in strength training, the emphasis must be on technique rather than the amount of weight lifted, and qualified supervision is essential to reduce the risk of injury.

As chronic childhood diseases (eg, obesity, diabetes, hypertension) become more prevalent among youth, it seems prudent to foster healthy lifestyles that are both effective for disease prevention and enjoyable. If appropriate training guidelines are followed, regular participation in a youth strength training program can increase bone mineral density, enhance motor performance, and better prepare young athletes for the demands of practice and competition. Thus, by getting children active at early age, strength training can foster healthy habits that may last a lifetime.

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## Definitions for Working Muscles

Various terms are used to describe the components of strength training programs. Muscle contractions may be either concentric (shortening of the contracting muscle, which overcomes the resistance) or eccentric (lengthening of the muscle that slowly yields to the resistance, thus stretching). Eccentric contraction occurs when a weight is lowered through the range of motion.

**Isometric contraction** ("same measure"), when opposing muscle groups resist each other, occurs without joint movement. Isometrics are usually done by applying pressure to an immovable object, but they may be done by simply contracting the muscles while holding the limbs still.

**Isotonic contraction** ("same tension") is limb or body movement against a dynamic constant load or resistance. Although isotonic contraction for training is done against resistance, all movements of the body are technically isotonic movements, but not all are done against resistance.

**Isokinetic contraction** ("same speed") is a dynamic resistance exercise performed at constant angular velocity that allows maximal contraction throughout the entire range of motion. The maximal force that can be achieved at any one point in the movement varies, and the speed of the movement also influences force.

**Plyometrics** are exercises in which concentric muscle action is immediately preceded by eccentric loading of the muscle (eg, long jump, rebounding in basketball).

**Repetition maximum (RM)** is the maximum amount of tension the muscle or muscle group can apply in a single effort. RM is used to measure muscle strength.

**Flexibility** refers to the range of motion in a joint or series of joints.

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**Disclosure information:** Drs Benjamin and Glow disclose no significant relationship with any manufacturer of any commercial product mentioned in this article. No drug is mentioned in this article for an unlabeled use.

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