Pediatric Resistance Training: Benefits, Concerns, and Program Design Considerations

Avery D. Faigenbaum and Gregory D. Myer

Department of Health and Exercise Science, The College of New Jersey, Ewing, NJ; Cincinnati Children’s Hospital Medical Center, Cincinnati, OH; Sports Medicine Biodynamics Center and Human Performance Laboratory, Cincinnati, OH; Rocky Mountain University of Health Professions, Provo, UT

FAIGENBAUM, A.D. and G.D. MYER. Pediatric resistance training: benefits, concerns, and program design considerations. Curr. Sports Med. Rep., Vol. 9, No. 3, pp. 161–168, 2010. A growing number of children and adolescents are involved in resistance training in schools, fitness centers, and sports-training facilities. In addition to increasing muscular strength and power, regular participation in a pediatric resistance training program may have a favorable influence on body composition, bone health, and reduction of sports-related injuries. Resistance training targeted to improve key fitness levels, poor trunk strength, and deficits in movement mechanics can offer observable health and fitness benefits to young athletes. However, pediatric resistance training programs need to be well-designed and supervised by qualified professionals who understand the physical and psychosocial uniqueness of children and adolescents. The sensible integration of different training methods along with the periodic manipulation of programs design variables over time will keep the training stimulus effective, challenging, and enjoyable for the participants.

INTRODUCTION

A growing number of young athletes are involved in resistance training in schools, fitness centers, and sports-training facilities (13,61). Over the past decade, evidence-based reports have emerged regarding both the safety and efficacy of resistance training in children and adolescents and the acceptance of pediatric resistance training by medical, fitness, and sport organizations has become widespread (2,3,13). Nowadays, physical education curricula include activities that improve muscular strength, and training programs specifically designed to enhance sports performance (especially among young athletes) have become a top 10 fitness trend for 2010 (58,72). Thus, as more children and adolescents get involved in resistance training in schools, health clubs, and sport training centers, it is important to establish safe and effective guidelines by which resistance exercise can improve the health, fitness, and sports performance of younger populations.

In this article, the term resistance training refers to a method of conditioning that involves the progressive use of a wide range of resistive loads, different movement velocities, and a variety of training modalities including weight machines, free weights (dumbbells and barbells), elastic bands, medicine balls, and body weight. The term resistance training is distinguished from the sports of weightlifting and powerlifting in which athletes periodically train with heavy loads and attempt to lift maximal amounts of weight in competition. For ease of discussion, the terms pediatric, youth, and young refer to children and adolescents.

POTENTIAL BENEFITS OF PEDIATRIC RESISTANCE TRAINING

While a majority of the pediatric research has focused on activities that enhance cardiorespiratory fitness, recent findings indicate that resistance training can offer unique benefits for children and adolescents when appropriately prescribed and supervised (13,48). In addition to enhanced muscular strength and motor skill performance, regular participation in a pediatric resistance training can facilitate weight control, strengthen bone, and increase a young athlete’s resistance to sports-related injuries (11,55). Further, since good health habits established during childhood may carry over into adulthood (71), the positive influence of these habits on the adult
lifestyle should be recognized by teachers, coaches, and health care providers. The potential benefits of pediatric resistance training are outlined in Table 1.

**Table 1. Potential benefits of pediatric resistance training.**

- Increase muscle strength
- Increase muscle power
- Increase local muscle endurance
- Enhance motor skill performance
- Increase bone mineral density
- Improve body composition
- Improve insulin sensitivity
- Improve blood lipid profile
- Reduce risk of sport-related injuries
- Enhance sports performance
- Stimulate a more positive attitude toward lifetime physical activity

**Body Composition**

The influence of resistance training on body composition has become an important topic of investigation, given that the prevalence of obesity among children and adolescents continues to increase (14). Although obese youth traditionally have been encouraged to participate in aerobic activities, excess body weight hinders the performance of weight-bearing physical activities such as jogging and increases the risk of musculoskeletal overuse injuries. Further, obese youth often lack the motor skills and confidence to be physically active, and they actually may perceive prolonged periods of aerobic exercise to be boring or discomforting. As noted by Stodden and colleagues, there is a “negative spiral of disengagement,” whereby youth with low levels of motor skill competence engage in less physical activity, which in turn leads to increased weight gain (69). In support of these observations, others observed that total body fat was inversely related to minutes of physical activity per day in children (10).

Although the treatment of pediatric obesity is complex, exposure to resistance exercise (along with behavioral counseling and nutrition education) may provide a gateway for overweight and obese youth to initiate exercise activities. From regular participation in resistance exercise, they may gain confidence in their ability to be physically active, which in turn may lead to a noticeable improvement in muscle strength, favorable changes in body composition, and an increase in regular physical activity (including recreational sports). Our observations suggest that overweight and obese youth enjoy resistance training because it is not aerobically taxing and it provides an opportunity for participants to enhance fitness performance while gaining confidence in their abilities to be physically active.

Several studies have reported favorable changes in body composition in children and adolescents who were obese or at risk for obesity following participation in a progressive resistance training program (44,65,67). Shaibi and colleagues observed a significant decrease in body fat and a significant increase in insulin sensitivity after 16 wk of resistance training in overweight adolescent males (65). Because overweight children and adolescents with low muscle fitness are reported to have the poorest metabolic risk profile (68), the protective effects of muscular fitness on metabolic health in youth should not be overlooked by health care providers who continue to embrace the challenge of dealing with overweight and obese youth.

**Bone Health**

The traditional fears and misinformed concerns that resistance training is harmful to the immature skeleton of young lifters have been replaced by scientific evidence that indicates that childhood and adolescence may be the opportune time for the bone-modeling and remodeling process to respond to the tensile and compressive forces associated with weight-bearing activities (3,73). If age-specific resistance training guidelines are followed with consumption of proper nutrients (e.g., adequate calcium and vitamin D) (4), regular participation in specialized fitness programs that include resistance exercise can play a critical role in bone mass acquisition during the pediatric years (73). Because low levels of peak bone mass are a significant risk factor of osteoporosis and associated fractures, regular participation in programs that maximize peak bone mass during childhood and adolescence may be an effective strategy for reducing the risk of osteoporosis later in life (25). While weight-bearing activities (particularly resistance exercise) can be an osteogenic stimulus during adulthood (22), resistance training may be most beneficial during childhood and adolescence because the mechanical stress from this type of training may act synergistically with growth-related increases in bone mass (3,73).

In support of these results, previous reports of adolescent weightlifters who regularly performed multijoint lifts with relatively heavy loads have been found to have levels of bone mineral density and bone mineral content significantly greater than age-matched control subjects (8,74). While additional clinical trials are needed to define more precisely the exercise prescription for optimizing bone development in youth, the importance of participating in sports and weight-bearing physical activities as a lifetime activity should not be overlooked, as training-induced gains in bone health may be lost over time if the program is not continued (23).

**Sports-Related Injuries**

Although the total elimination of sports-related injuries is an unrealistic goal, appropriately designed and sensibly progressed conditioning programs that include resistance training may help reduce the likelihood of sports-related injuries in young athletes. Owing to the apparent decline in free time physical activity among children and adolescents (57,59), it seems that the musculoskeletal system of some aspiring young athletes may not be prepared for the demands of sports practice and competition. In one study, it was reported that children engaged in approximately 3 h·d⁻¹ of moderate to vigorous physical activity (MVPA), but adolescents were only engaging in MVPA for 49 min·d⁻¹ on weekdays and 35 min·d⁻¹ on the weekend (57). Consequently, the supporting structures of some young athletes may be ill-prepared...
to handle the demands of weekly sports practice sessions and weekend competitions.

By addressing the risk factors associated with youth sport injuries (e.g., low fitness level, muscle imbalances, and errors in training), Micheli suggested that both acute and overuse injuries could be reduced by 15%–50% (46). Heidt and colleagues were able to significantly reduce injury rates with the addition of a preseason conditioning regimen in adolescent female soccer players (26). Cahill and Griffith incorporated resistance training into their preseason program for adolescent football teams and reported a reduction in nonsurgical and surgical knee injuries over four competitive seasons (5). Hejna et al. reported that young athletes (13–19 yr) who incorporated resistance training in their exercise regimen suffered fewer injuries and recovered from injuries with less time spent in rehabilitation compared with teammates who did not resistance train (28). Protocols incorporating resistance training into preseason and inseason conditioning programs are predictive of future injury risk as well as anterior cruciate ligament injuries in adolescent female athletes (29,32). While there is not one combination of exercises, sets, and repetitions that has proven to optimize training adaptations, these data indicate that multifaceted programs that increase muscle strength, enhance movement mechanics, and improve functional abilities appear to be the most effective strategy for reducing sports-related injuries in young athletes.

Clearly, participation in physical activity should not begin with competitive sport but should evolve out of preparatory fitness conditioning that is sensibly progressed over time. Although there are many mechanisms to potentially reduce sports-related injuries (e.g., coaching education, safe equipment, proper nutrition), enhancing physical fitness as a preventative health measure is considered a cornerstone of multi-component programs for school-aged youth. This is an important consideration for health care providers who often perform preparticipation physical examinations to assess a young athlete’s readiness for sport (35). In addition to the medical examination (including a musculoskeletal assessment), health care providers should inquire about a patient’s participation in physical activities over the past few months. Because training errors (e.g., “too much, too soon.”) are a common theme in many sports-related injuries in youth (46), there is an ongoing need to ensure that aspiring young athletes participate in multi-component conditioning programs before the start of the sport season and continue training in a modified program throughout the competitive season.

**SPECIAL CONSIDERATIONS FOR TRAINING FOR GIRLS**

While musculoskeletal growth and development show very similar trends between genders, male and female strength and coordination (neuromuscular) patterns diverge significantly during and after puberty (31). Boys naturally demonstrate that power, strength, and body coordination increase with chronological age, which correlates to maturation stage, whereas untrained girls on average show little improvement in strength, balance, and power throughout puberty (31,35,43,62). For example, vertical jump height (a measure of whole-body power) increases steadily in boys during puberty but not in girls (62). This puberty-related divergence in neuromuscular development between boys and girls may explain, at least in part, gender-related differences in injury risk observed in post-pubertal female athletes (1,33,35).

Multifaceted training programs that combine resistance training, plyometric training (with education on jumping and landing techniques), postural balance, and body position control (proprioception) have been found to enhance movement biomechanics and lower extremity strength in adolescent girls (49–55). Observed relative gains in girls may be greater than in boys because baseline neuromuscular performance levels are lower on average in girls versus boys (20,35,40,54,62). Girls have been shown to improve strength measures up to 92% with just 6 wk of training (54). In addition to reduced knee injuries in adolescent (30) and mature female athletes (56), regular participation in a multifaceted resistance training program also may induce measures of the “neuromuscular spurt,” which typically are not seen in females (54). Of potential interest to sports medicine professionals, resistance training timed with growth and development may induce the desired neuromuscular spurt, which may improve sports performance and improve biomechanics related to injury risk in young girls (34,54). Cumulatively, these findings indicate that young female athletes should participate regularly in multifaceted resistance training programs.

**RISKS AND CONCERNS**

Current findings from pediatric resistance training studies indicate a low risk of injury in children and adolescents who follow age-appropriate training guidelines (18,24,42). A traditional concern associated with youth resistance training is the potential for injury to the physis or growth plate in a young lifter’s body. The growth plate can be three to five times weaker than surrounding connective tissue, and it may be less resistant to shear and tension forces (66). Injury to this section of bone could result in time lost from training, significant discomfort, and growth disturbances (6). Although a few retrospective case reports noted injury to the growth cartilage in youth (18), most of these injuries were caused by improper lifting techniques, poorly chosen training loads, or lack of qualified adult supervision. For example, in one case report, a 13-yr-old boy suffered bilateral fracture separations of the distal radial epiphyses when he lost control of a barbell as he attempted to press a 30-kg weight overhead while exercising alone in a “makeshift gymnasium” at home (38). It is unclear from this report whether this teenager received instruction on proper resistance training procedures or if he was involved in an activity without qualified supervision. Future reports should provide details of predisposing factors to better understand the true risk of injury to the physis in young lifters.

Injury to the growth cartilage has not been reported in any prospective youth resistance training research study, and there is no evidence to suggest that resistance training will negatively impact growth and maturation during childhood and adolescence (18,42). To date, only three published
training studies have reported resistance training-related injuries in young lifters, namely, anterior shoulder pain that resolved within 1 wk of rest (63), a strain of a shoulder muscle that resulted in one missed training session (41), and nonspecific anterior thigh pain that resolved with 5 min of rest (64). A review of these findings revealed estimated injury rates of 0.176, 0.053, and 0.055 per 100 participant hours, respectively, which suggests that supervised resistance training protocols are relatively safe for youth (18). Significant gains in strength without any report of injury also have been reported in prospective studies in which weightlifting movements (including modified cleans, pulls, and presses) were incorporated into youth resistance training programs (7,16,21).

While the available data indicate that the injury occurrence in pediatric resistance training studies is either very low or nil (18,24,42), professionals who prescribe resistance exercise should be mindful of the inherent risk associated with this type of training, cognizant of safety precautions, and aware of the potential risk for repetitive use soft-tissue injuries. For example, Quatman and colleagues reported that the trunk was the most frequently injured body part for both men and women between the ages of 14 and 30 yr who presented to U.S. emergency departments from weightlifting injuries (61). Since lower back pain has become a significant health concern among adolescents (37), there appears to be a role for preventative interventions that enhance the strength, local muscular endurance, and stability of the lower back to reduce the prevalence or severity of lower back injuries in young lifters. From our experience, some young lifters spend too much time training their “mirror muscles” (e.g., chest: bench press; arms: biceps curl) and not enough time (or no time at all) strengthening their trunk or posterior chain musculature. Thus, observed injuries to the lower back in young lifters may be due, at least in part, to poor program design. Other factors such as improper exercise technique and inappropriate progression of training loads also may increase the risk of soft-tissue injury.

If pediatric resistance training guidelines are not followed, there is the potential for serious injury. For example, it has been reported that unsafe behavior, equipment malfunction, and lack of qualified supervision increase the risk of injury in young children who exercise at home (39). Myer and colleagues recently reported that two-thirds of resistance training-related injuries sustained by 8- to 13-yr-old patients who reported to emergency departments in the United States were to the hand and foot, and most were related to “dropping” and “pinching” (47) (Fig. 1). These findings underscore the importance of qualified supervision, safe exercise equipment, and strict adherence to pediatric resistance training guidelines at home, school, and sports-training centers.

**PEDIATRIC RESISTANCE TRAINING GUIDELINES**

A prerequisite for the development and administration of safe, effective, and enjoyable youth resistance training programs is an understanding of established training principles and an appreciation for the physical and psychosocial uniqueness of children and adolescents. Qualified and enthusiastic instruction not only enhances participant safety and enjoyment, but direct supervision of youth resistance training programs can improve program adherence and optimize strength gains (9). Although there is no minimum age requirement at which children can begin resistance training, all participants must be mentally and physically ready to comply with coaching instructions and undergo the stress of a training program. In general, if a child is ready for participation in sport activities (generally age 7 or 8), then he or she is ready for some type of resistance training.

There does not appear to be one optimal combination of sets, repetitions, and exercises that will promote favorable adaptations in young athletes. Rather, the sensible integration of different training methods and the periodic manipulation of program variables over time will keep the training

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**Figure 1.** Percentage of injuries of the oldest and youngest age categories. Note that the small prevalence of leg injuries in the 8–13 yr age categories provides invalidated results and should be interpreted with caution. (Reprinted from Myer GD, Quatman CE, Khoury J, Wall EJ, Hewett TE. Youth vs. adult "weightlifting" injuries presenting to United States emergency rooms: accidental vs. non-accidental injury mechanisms. *J. Strength Cond. Res.* 2009; 23:2054–60. Copyright © 2009 National Strength and Conditioning Association. Used with permission.)

164 Current Sports Medicine Reports www.acsm-csmr.org
stimulus effective, challenging, and pleasurable for the participants. We refer to this concept as fitness integration because it incorporates a combination of performance-enhancing and injury-reducing components (e.g., strength, power, and balance) into one fitness program. This type of training does not necessitate expensive equipment, but it does require qualified instruction, a systematic progression of training variables, and an understanding of pediatric resistance exercise guidelines (3,13). In short, the act of resistance training in and of itself does not ensure that favorable changes in fitness and performance will be realized. Rather, individual effort combined with a well-designed training program ultimately will determine the adaptations that take place.

When designing resistance training programs for young athletes, it is important to consider the total exercise dose, which includes sports practice and competition as well as free play, physical education, and possibly private training sessions. Some young athletes with relatively immature musculoskeletal systems may not be able to tolerate the same exercise dose as their teammates. Because of the interindividual variability of stress tolerance, each young athlete should be treated as an individual, and coaches must be aware of incipient signs of overtraining, which would require a modification of the training program. A reduction in sports performance and an increased risk of injury can result if resistance exercises are simply added onto a young athlete’s training schedule.

The acute program design variables that should be considered when designing pediatric resistance training programs include 1) warm-up and cool-down, 2) selection and order of exercise, 3) training intensity and volume, 4) rest intervals between sets and exercises, and 5) repetition velocity. Table 2 summarizes pediatric resistance training guidelines. Detailed descriptions of pediatric resistance training programs using different types of equipment are beyond the scope of this article but are available elsewhere (13,45,50).

Warm-Up and Cool-Down

Over the past few years, long-held beliefs regarding the routine practice of warm-up static stretching have been questioned. Lately, there has been rising interest in warm-up procedures that involve the performance of dynamic movements (e.g., hops, skips, jumps, and movement-based exercises for the upper and lower body) designed to elevate core body temperature, enhance motor unit excitability, improve kinesthetic awareness, and maximize active ranges of motion. Warm-up protocols that include moderate- to high-intensity dynamic movements have been found to enhance power performance in young athletes (12,17). A reasonable suggestion is to perform 5–10 min of dynamic activities (e.g., jumping, skipping, and lunging) during the warm-up period and less intense calisthenics and static stretching at the end of the workout.

Selection and Order of Exercise

Weight machines (both child-sized and adult-sized) as well as free weights, elastic bands, medicine balls, and body weight exercises have been used by children and adolescents in clinical- and school-based exercise programs (3,15,55). While each mode of training has advantages and disadvantages, it is important to select exercises that are appropriate for a participant’s body size, fitness level, exercise technique experience, and training goals. It is desirable to start with relatively simple exercises and gradually progress to more advanced multijoint movements as confidence and competence improve.

From our experience, resistance training with free weights, medicine balls, and one’s own body weight may be particularly beneficial for young athletes who need to enhance motor skill performance, balance, core strength, and muscle power as part of an integrated training program. Increased dynamic balance may help to provide young athletes with a stable core (i.e., pelvis, abdomen, trunk, and hip) that will be better prepared to respond to the high forces generated at the distal body parts during athletic competition (50). During peak height velocity in pubertal athletes, the tibia and femur grow at relatively rapid rates in both sexes (31,70). Rapid growth of the two longest levers (tibia and femur) initiate height increases that concurrently increase height of the center of mass, making muscular control of the trunk more difficult (31,35,50).

Although the isolated effects of core training and balance training on measures of performance have not been demonstrated clearly, the potential benefits of this type of training likely are substantial and combinatory to other modes of conditioning (27). For example, core strengthening and balance training can improve dynamic balance, which may help provide an athlete with a dynamically stable core that can be better prepared to respond to the high forces generated at the distal body parts during athletic competition (36,60). While further study is warranted, the global effects of core strength gains may be best attained with the integration of core strengthening and balance training into a multifaceted resistance training program. Overhead training exercises such as the unilateral loaded walking lunge press are designed to simultaneously improve core strength and dynamic stability during a multiplanar movement progression (Fig. 2).

There are many ways to arrange the sequence of exercises in a resistance training session. Most youth will perform total body workouts several times per week, which involve multiple exercises stressing all major muscle groups each session. In

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**TABLE 2.** General pediatric resistance training guidelines.

- Provide qualified instruction and close supervision
- Ensure the exercise environment is safe and free of hazards
- Begin each session with a dynamic warm-up
- Focus on developing proper exercise technique and learning fundamental training principles
- Perform 1–3 sets of 6–15 repetitions on strength exercises
- Perform 1–3 sets of 6 or fewer repetitions on power exercises
- Perform exercises for the upper body, lower body, and midsection
- Include exercises that require balance and coordination
- Cool down with less intense activities and stretching
- Resistance train 2–3 times each week on nonconsecutive days
- Keep the program fresh and challenging by systematically varying the training program.
this type of workout, large muscle group exercises should be performed before smaller muscle group exercises, and multiple-joint exercises should be performed before single-joint exercises. Of note, it is desirable to perform more challenging exercises earlier in the workout when the neuromuscular system is less fatigued. Thus, if a child is learning how to perform a weightlifting movement or a plyometric exercise, this type of exercise should be performed early in the training session so that the child can practice the exercise without undue fatigue.

Training Intensity and Volume

Training intensity typically refers to the amount of resistance used for a specific exercise, whereas training volume generally refers to the total amount of work performed in a training session. While both of these program variables are significant, training intensity is one of the more important factors in the design of a resistance training program because it is the major stimulus related to changes in muscular fitness. However, to maximize gains in muscular fitness and reduce the risk of injury, youth must first learn how to perform each exercise correctly with a light load (e.g., unloaded barbell) and then gradually progress the training intensity and/or volume without compromising exercise technique.

A simple approach may be to first establish the repetition range, and then by trial and error determine the maximum load that can be handled for the prescribed range. For example, a young lifter may begin resistance training with one or two sets of 10–15 repetitions with a light or moderate load in order to develop proper exercise technique. Depending on individual needs, goals, and abilities, over time the repetition range can be progressed to include additional sets with heavier loads (e.g., 6–10 repetition maximum) on large muscle group exercises to maximize gains in muscle strength. Because of the relative complexity of power exercises (e.g., plyometric or weightlifting movements), note that youth typically perform fewer quality repetitions (≤6) in order to maintain movement speed and efficiency for all repetitions within a set. As training programs become more advanced (and potentially more intense), the importance of reinforcing proper exercise technique and training habits should not be overlooked. Moreover, by periodically varying program variables, long-term performance gains will be optimized, the likelihood of boredom will be reduced, and risk of overuse injuries may decrease.

Rest Intervals Between Sets and Exercises

The length of the rest interval between sets and exercises is an important but often overlooked program variable. While rest intervals of 2–3 min typically are recommended for adult lifters, this guideline may not be consistent with the needs and abilities of younger populations due to growth- and maturation-related differences in response to physical exertion. The available data suggest that children and adolescents can resist fatigue to a greater extent than adults during several repeated sets of resistance exercise (19). Thus, a shorter rest interval (about 1 min) may suffice in children and adolescents when performing a moderate-intensity resistance exercise protocol, although the likelihood that youth with lower levels of strength may recover faster than youth with higher levels of strength should be considered.

Repetition Velocity

The velocity or cadence at which a resistance exercise is performed can affect the adaptations to a training program. While it generally is recommended that youth resistance-train in a controlled manner at a moderate velocity, different training velocities may be used depending on the choice of exercise. For example, plyometric exercises and weightlifting movements are explosive but highly controlled movements that are performed at a high velocity. As part of an integrated resistance training program, we believe that the performance of different training velocities within a training program may provide the most effective training stimulus for young athletes. However, as youth increase movement velocity during training, it is critical that technical performance of each exercise is mastered before progressing to more advanced movements. Instructors should monitor every training session and provide constructive feedback to ensure that athletes maintain proper technical performance of all exercise movements.

CONCLUSION

Scientific evidence and clinical impressions indicate that resistance training has the potential to offer observable...
health and fitness value to children and adolescents, provided that appropriate training guidelines are followed and qualified instruction is available. Comprehensive resistance training programs that integrate different elements of physical fitness are most likely to enhance sports performance and reduce the risk of injury. These benefits can be obtained safely by most youth who train under the supervision of a qualified coach and follow age-appropriate resistance training guidelines. Important future research goals should aim to elucidate the mechanisms responsible for the performance enhancement and injury reduction benefits associated with pediatric resistance exercise in order to establish the combination of program variables that may optimize long-term training adaptations and exercise adherence in children and adolescents.

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References


