

YOUTH RESISTANCE TRAINING: POSITION STATEMENT PAPER AND LITERATURE REVIEW

Position Statement

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The popularity of resistance training among prepubescents and adolescents has increased, and the qualified acceptance of youth resistance training by professional organizations is becoming universal (4, 6, 7, 91). Despite the old belief about youth resistance training being ineffective and unsafe, resistance training is now recognized as an important component of youth fitness programs, health promotion objectives, and injury prevention strategies (5, 34).

The National Strength and Conditioning Association (NSCA) recognizes and supports the premise that many of the benefits associated with adult resistance training programs are attainable by prepubescents and adolescents who follow age-specific resistance training guidelines. The NSCA has based this position statement paper on a comprehensive analysis of the pertinent scientific evidence regarding the anatomical, physiological, and psychosocial effects of youth resistance training. A committee of 11 professionals with clinical and research expertise on issues related to youth resistance training contributed to this paper. Committee members reviewed and revised this paper prior to the formal endorsement by the NSCA.

The focus of this paper is on the benefits and concerns associated with regular, moderate intensity youth resistance training programs. The term *youth* is broadly defined as the period of life that includes both the prepubescent and adolescent years. Resistance training is defined as a specialized form of conditioning that is used to increase one's ability to exert or resist force (7). Resistance training is distinct from the competitive sports of powerlifting and weightlifting in which individuals regularly train at high intensities and attempt to lift maximal amounts of weight.

This paper builds on previous recommendations from the NSCA and should serve as the prevailing statement on youth resistance training. It is the current position of the NSCA that:

1. A properly designed and supervised resistance training program is safe for children.
2. A properly designed and supervised resistance training program can increase the strength of children.
3. A properly designed and supervised resistance training program can help to enhance the motor fitness skills and sports performance of children.
4. A properly designed and supervised resistance training program can help to prevent injuries in youth sports and recreational activities.
5. A properly designed and supervised resistance training program can help to improve the psychosocial well-being of children.
6. A properly designed and supervised resistance training program can enhance the overall health of children.

Literature Review

■ Risks Associated With Youth Resistance Training

During the 1970s and 1980s, one of the reasons that resistance training was not often recommended for the immature athlete was the presumed high risk of injury associated with this type of exercise. In part, the widespread fear of injury associated with youth resistance training during this era stemmed from data gathered by the National Electronic Injury Surveillance System (NEISS) of the U.S. Consumer Product Safety Commission. NEISS uses data from various hospital emergency rooms to make nationwide projections of the total number of injuries related to exercises and equipment.

It was reported (130) in 1979 that over half of the 35,512 weightlifting injuries requiring emergency room treatment involved 10- to 19-year-olds, and a 1987 report (131) revealed that 8,590 children ages 14 and under were taken to the emergency room because of injuries related to weightlifting. The NEISS reports, however, did not distinguish between injuries associated with resistance training and those associated with the competitive sports of powerlifting and weightlifting. Moreover, since the NEISS data were based on injuries that patients *said* were related to weightlifting exercises and equipment, it is incorrect to conclude the injuries were indeed caused by such activities and devices.

The most common resistance training injuries in the NEISS reports were sprains and strains, although more serious injuries such as epiphyseal fractures and lumbosacral injuries have been noted in the literature (100, 101). However, nationwide projections of emergency room visits and case series reports of injured young athletes provide limited information on the predisposing factors of these injuries. In fact many of the reported injuries were actually caused by poor training, excessive loading, poorly designed equipment, free access to the equipment, or lack of qualified adult supervision. Although these findings indicate that the unsupervised use of heavy resistive loads in training or competition may be injurious, it is misleading to generalize these findings to properly designed and closely supervised youth resistance training programs.

Generally, the risk of injury associated with resistance training is similar for children and adults. But a traditional area of concern in children is the potential for training-induced damage to the epiphy-

sis, or growth plate, of their long bones. The epiphysis is the weak link in the young skeleton because the strength of cartilage is less than that of bone (20). In some cases, damage to this area of the bone could cause the epiphysis to fuse, resulting in limb deformity and/or the cessation of limb growth (77, 89, 115).

A few retrospective case reports have noted epiphyseal plate fractures during adolescence (11, 19, 61, 75, 104, 106); however, most of these injuries were due to improper lifting techniques, maximal lifts, or lack of qualified adult supervision. Technique related injuries often involved the aggressive use of free weights in such exercises as the deadlift, bench press, and overhead press (21, 61, 106), although injuries involving weight machines are also possible (19).

Both prepubescents and adolescents are susceptible to growth plate injuries, yet it appears that the potential for this injury in a prepubescent child may be less than in an adolescent because the growth plates may actually be stronger and more resistant to sheering type forces in the younger child (90). Growth plate fractures have not been reported in any prospective resistance training studies that were characterized by appropriately prescribed training regimens and competent instruction.

The potential for repetitive-use soft-tissue injuries is also of concern when children undergo resistance training. This type of injury does not often result in emergency room visits or even physician visits, so the incidence of these injuries is more difficult to determine. Nevertheless, several retrospective studies on adolescents have associated lower back soft-tissue injuries with resistance training. In fact, lumbosacral pain was found to be the most frequent injury in high school athletes who participated in resistance training programs (19, 101).

In one report (19), however, a majority of the injuries to the lumbar spine may be attributable to the improper use of a device designed to improve vertical jump. A study of adolescent powerlifters who presumably trained with maximal or near-maximal resistances revealed that 50% of reported injuries were to the lower back, 18% to the upper extremity, 17% to the lower extremity, and 14% to the trunk (21). Although these studies involved adolescents, the potential for similar injuries in prepubescents should be recognized. Based on available evidence and clinical observations, training-induced injuries to the lower back seem to pose a noteworthy concern for clinicians and coaches (73, 84, 108, 135).

Prospective studies on resistance training in children indicate a low risk of injury. In most of the published studies, no overt clinical injuries having been reported during the resistance training program. Although various training modalities and a variety of training regimens have been used, all the training programs were closely supervised and appropriately prescribed to ensure that the program was matched to the initial capacity of the child.

Only two published studies have reported resistance training injuries in children: a shoulder strain that resolved within 1 week of rest (99) and an undefined "minor" injury (22). The former study (99) found no evidence of either musculoskeletal injury (measured by biphasic scintigraphy) or muscle necrosis (determined by serum creatine phosphokinase levels) following 14 weeks of progressive resistance training. Generally, the risk of injury consequent to resistance training programs is very low, provided that appropriate training guidelines are followed.

Resistance training in children, as with most physical activities, does carry some degree of inherent risk of musculoskeletal injury. Yet this risk is no greater than that in many other sports or recreational activities in which children regularly participate. In one prospective study that evaluated the incidence of sports related injuries in schoolchildren over a 1-year period (144), resistance training resulted in 0.7% of the 1,576 reported injuries whereas football, basketball, and soccer resulted in approximately 19, 15, and 2%, respectively, of all injuries. When the data were evaluated in terms of injury to participant ratio in school team sports, football (28%), wrestling (16.4%), and gymnastics (13%) were at the top of the list.

A retrospective evaluation of resistance training and weightlifting injuries incurred primarily by 13- to 16-year-olds revealed that both resistance training and weightlifting are markedly safer than many other sports and activities (65). Moreover, the results of that study indicated that the rate of injury for weightlifting was lower than for resistance training. In part, this may be explained by the fact that weightlifting is typically characterized by knowledgeable coaching and the gradual progression of training loads which are required to learn the proper technique of advanced multijoint lifts.

In some countries, children as young as 8 years of age are taught advanced multijoint lifts (79), although weight is not added to the bar until they reach the age of 12 or 13. The potential for injury during the performance of multijoint free-weight exercises should not be overlooked, however (101).

There is the potential for a catastrophic injury if safety standards for youth resistance training—qualified supervision, safe equipment, and age-specific training guidelines—are not followed (60). One case study (56) reported a 9-year-old boy died when a barbell rolled off a bench press support and fell on his chest. This fatality underscores the importance of providing close adult supervision and safe training equipment for all youth resistance training programs.

Any exercise or activity for children carries risks as well as benefits. Although resistance training injuries will occur, the risk can be minimized by close adult supervision, proper instruction, appropriate program design, and careful selection of training equipment. There are no justifiable safety reasons to preclude prepubescents or adolescents from participating in a properly designed and supervised resistance training program.

■ Effectiveness of Youth Resistance Training

In the past it was presumed that training-induced strength gains during prepubescence were not possible because of insufficient levels of circulating androgens (3). The results from a few studies (37, 69, 133) were believed to support this claim, despite the fact that methodological limitations may have influenced the results. A majority of the scientific evidence within the past 10 years, however, strongly suggests that children can significantly increase their strength—above and beyond growth and maturation—provided that the resistance training program is of sufficient duration and intensity (22, 35, 44, 46, 48, 54, 72, 85, 96, 98, 107, 111, 112, 114, 119, 137, 139, 140, 141).

During childhood, many physiological changes related to growth and development are occurring at a rapid rate. Muscular strength, defined as the maximal force a muscle or muscle group can generate, normally increases from childhood through the early teenage years, at which time strength accelerates markedly in boys and plateaus in girls (83). Thus strength changes from a low volume (sets × repetitions × load), short-duration training program may not be distinguishable from gains due to normal growth and development. In order to differentiate training adaptations from those of normal growth and development, it is apparent that a prolonged period of time and an adequate training stimulus are required.

A recent meta-analysis on resistance training and children (33), as well as scientific review papers (14, 15, 41, 51, 78, 89, 108, 135, 136) and clinical

observations (9, 90), have reported that well-designed resistance training programs can enhance the strength of prepubescents and adolescents beyond what is normally due to growth and development. Children as young as age 6 have benefited from resistance training (48), and studies have lasted up to 9 months (119).

A wide variety of progressive resistance training programs, from 1 set of 10 repetitions (140) to 5 sets of 15 repetitions (72), have proven efficacious. Training modalities have included weight machines, both adult (35, 85, 96, 98, 112, 133, 141) and child size (44, 46, 140), free weights (22, 35, 98, 107, 111), hydraulic machines (137), pneumatic machines (112), isometric contractions (54, 69, 93), wrestling drills (29), modified pull-ups (10), and calisthenics (48, 114).

Comparative Trainability

Strength gains up to 74% have been reported (46) following 8 weeks of progressive resistance training, although gains of roughly 30 to 50% are typically observed following short-term (8 to 20 weeks) resistance training programs in children. There is no clear evidence of any major difference in strength, as measured by selected strength tests, between prepubescent boys and girls (13, 108). Reported relative (percent improvement) strength gains during prepubescence are equal to if not greater than the relative gains observed during adolescence (93, 96, 139).

In terms of absolute strength, it appears that adolescents make greater gains than prepubescents (108, 133), and adults make greater gains than young adolescents (107), although some findings are at variance with this suggestion (139). The issue of whether the training-induced changes observed in prepubescents and adolescents should be compared on a relative or absolute basis is debatable (108).

Persistence of Training-Induced Strength Gains

The evaluation of strength changes in children following the temporary or permanent reduction or withdrawal of a training stimulus (referred to as detraining) is complicated by the concomitant growth related strength increases during the same time period (14). Few studies have evaluated the effects of detraining in adults, and relative information on younger populations is even more scarce. Nevertheless, limited data suggest that training-induced strength gains in children are impermanent and tend to regress toward untrained control group values during a detraining period (17, 44, 72, 112). The precise nature of the detraining response and the physiological adaptations that occur during this pe-

riod remain uncertain, although changes in neuromuscular functioning would appear to play a significant role at least during prepubescence.

Only a few studies have evaluated the effects of training frequency on strength maintenance in children. Following 20 weeks of progressive resistance training, a once-weekly maintenance training program was not enough to maintain the training-induced strength gains in prepubescent boys (17). Conversely, another study found that for a group of pubescent male athletes (35), a 1-day-a-week maintenance program was just as sufficient as a 2-day-a-week maintenance program in retaining the strength gains made after 12 weeks of resistance training. Clearly, more information is required before specific maintenance training recommendations can be made.

Program Evaluation and Testing

Factors such as previous exercise experience, program design, specificity of testing and training, choice of equipment, quality of instruction, and whether or not the learning effect was controlled for in the study can directly influence the degree of measured strength change. In addition, the methods of evaluating changes in muscular strength consequent to training are noteworthy considerations. In several studies the subjects were trained and tested using different modalities (96, 112, 137), and in many of the published reports, strength changes were evaluated by relatively high-repetition maximum (RM) values (e.g., 10-RM) (46, 140). Except for a few studies (35, 95, 98), strength changes were rarely evaluated by maximal load lifting (i.e., 1-RM testing) on the equipment used in training.

Many clinicians and researchers have not used 1-RM testing to evaluate training-induced changes in muscular strength because of the presumption that high intensity loading may cause structural damage in children. Thus the maximal force production capabilities of children have not been directly evaluated in most studies. Yet no injuries have been reported in prospective studies that used adequate warm-up periods, appropriate progression of loads, close and experienced supervision, and critically chosen maximal strength tests (1-RM performance lifts, maximal isometric tests, and maximal isokinetic tests) to evaluate resistance-training-induced changes in children (35, 95, 98).

The examination of the relative safety of supervised 1-RM testing in laboratory settings performed only to evaluate training-induced changes in muscular strength should be supported philosophically. Most of the forces that children are exposed to in

sports and recreational activities are likely to be greater in both duration and magnitude of exposure than competently supervised and properly performed maximal strength tests. Conversely, under no circumstances should children be subjected to unsupervised and poorly performed 1-RM testing (e.g., inadequate progression of loading and poor lifting technique) or chronic maximum resistance training (e.g., weightlifting training without periodization), due to the real risk of injury (100, 101, 142).

Physiological Mechanisms for Strength Development

In prepubescents it appears that training-induced strength gains are more related to neural mechanisms than to hypertrophic factors (78, 95, 98, 108). Without adequate levels of circulating testosterone to stimulate increases in muscle size, prepubescents apparently have more difficulty increasing their muscle mass consequent to a resistance training program (up to 20 weeks) as compared to older populations (95, 98, 133). However, since some findings are at variance with this suggestion (53, 88), it cannot be stated a priori that resistance training will not increase the muscle mass of prepubescents. It is possible that more intensive training programs and advanced measuring techniques (e.g., computerized imaging) may be needed to distinguish the effects of training on fat free mass from any expected gains due to growth and maturation.

Without corresponding increases in fat free mass, it appears that neural adaptations—a trend toward increased motor unit activation and changes in motor unit coordination, recruitment, and firing (95, 98)—and possibly intrinsic muscle adaptations, as evidenced by increases in twitch torque (98), are primarily responsible for training-induced strength gains during prepubescence.

Improvements in motor skill performance and the coordination of the involved muscle groups may also play a significant role, since measured increases in training-induced strength are typically greater than changes in neuromuscular activation (95, 98). In support of these findings, several training studies (46, 85, 95, 98, 107, 137) have reported significant improvements in strength during prepubescence without corresponding increases in gross limb morphology, when compared to similar control groups.

During puberty, testicular testosterone secretion is associated with considerable increases in fat-free mass (78, 82, 113). Training-induced strength gains during and after puberty in males may therefore be associated with changes in hypertrophic

factors, since hormonal influences on muscle hypertrophy would be operant (78). Lower levels of androgens in females limit the magnitude of training-induced increases in muscle hypertrophy (108). Other hormone and growth factors (e.g., growth hormone and insulin-like growth factors) may be at least partly responsible for muscle development in females (76).

■ Motor Fitness Skills and Sports Performance

Improvements in selected motor fitness skills have been observed in children following resistance training programs (48, 93, 137, 141). Several studies have reported increases in the long jump or vertical jump (48, 93, 137, 141), and one study (141) noted increases in 30-meter dash time and agility run time. In contrast, two studies (22, 46) have reported significant increases in strength without concomitant improvements in selected motor performance skills after several weeks of progressive resistance training.

Since the effects of resistance training depend on the duration, frequency, speed, and volume of the training stimulus, confounding variables in the program design may partly explain these inconsistent findings. Moreover, the effects of resistance training on motor fitness skills must be distinguished from those associated with growth and maturation.

The principle of training specificity must be considered when evaluating the effects of resistance training on selected motor fitness skills. It appears that training adaptations in children are rather specific to the movement pattern, velocity of movement, contraction type, and contraction force (64). The specificity of training and possible transfer to related activities was observed in 249 females, ages 7 to 19, who participated in a 5-week training program (93). They trained for a particular test—sprint acceleration, vertical jump, or isometric strength—by either running, jumping, or performing isometrics. Regardless of age, the greatest improvements were made in the activity for which the subjects trained, although some degree of transfer to nonspecific movements was noted. As previously observed in adults (109), it appears that the major training adaptations in children are exercise-specific.

The potential for resistance training to enhance sports performance in children seems reasonable because many sports in which children participate have a significant strength or power component. Moreover, if stretching exercises are part of the resistance training program, flexibility has been shown to improve significantly (114, 137). Comments from

parents whose children have participated in a resistance training program suggest that resistance training enhances athletic ability (41, 137).

Scientific evaluations of this observation are difficult to make because athletic performance is such a multivariate gestalt (78). There have not been any long-term investigations on the effects of a comprehensive preseason resistance training program on improved sports performance in children. This information would be beneficial, as it would enable a better understanding of the effects of resistance training on youth sports performance. It would also help evaluate the potential for carryover into adulthood.

Two studies (12, 23) have reported favorable changes in swim performance in age-group swimmers, and another study (97) has demonstrated significant improvements in strength and selected gymnastic events in prepubescent girls following a resistance training program. Conversely, one short-term isometric training program did not improve swim speed in 7- to 17-year-old swimmers (2), and a resistance training program, as compared to basketball practice, did not significantly influence selected basketball skills in 14- and 15-year-old boys (50).

Conclusions as to the effects of resistance training on sports performance during prepubescence and adolescence are equivocal. Collectively, however, limited direct and indirect evidence, as well as observations on older populations (49, 145), suggest that a commonsense sport-specific resistance training program will result in some degree of improvement in athletic performance. It would seem reasonable to curtail preseason and inseason practice sessions to allow time for sport-preparatory resistance training, provided that the training program is competently supervised, progressive, and of sufficient duration and intensity. Since children cannot "play" themselves into shape, one of the greatest benefits of youth resistance training may be its ability to better prepare them for participation in sports and recreational activities.

■ Prevention of Injuries

The popularity of sports participation over the last 20 years by children in this country has grown enormously. Approximately 30 million children (roughly 50% of the boys and 25% of the girls) play competitive organized sports, and many others participate in community-based sport programs. Along with this increase in sports participation have come numerous reports of injuries to ill-prepared and improperly trained young athletes (28, 94). Appropriately de-

signed and supervised resistance training programs may help prevent such injuries.

Resistance training appears to be an effective injury-prevention strategy for adults, and similar mechanisms may help decrease the prevalence of injury in youth sports (27, 103). The mechanisms by which improving muscle strength might prevent or lessen the severity of an injury include the strengthening of supporting structures (i.e., ligaments, tendons, and bones) (31, 118, 123), the enhanced ability of a trained muscle to absorb more energy prior to failure (55), and the development of muscle balance around a specific joint (67). A year-round strength training program was found to decrease the incidence of injuries in college soccer players (80), and the elimination of muscle imbalances in college football players decreased the incidence and recurrence of hamstring injuries (67).

Only a few studies have demonstrated a decreased injury rate in adolescents who have undergone resistance training (24, 38, 68). A preseason conditioning program that included resistance training led to a decrease in the number and severity of injuries in high school football players (24). Similarly, resistance training decreased the incidence of shoulder problems in teenage swimmers (38) and older athletes (66).

In one report involving high school male and female athletes, the injury rate for those who performed resistance training was 26.2%, compared to 72.4% for athletes who did not perform resistance training (68). Furthermore, the time required for rehabilitation was only 2.02 days for the former group versus 4.82 days for the latter group. Even though a motivated athlete who is injured may be more likely to return to practice early and endure some pain, he or she may also be used more in competition and thereby risk further injury.

Although it is tempting to generalize these positive findings to prepubescents, the differences in quality and quantity of sport training, degrees of aggressiveness and competition, and participation rates in contact and noncontact sports should also be considered (16).

Moreover, the addition of resistance training to the total exercise picture, which includes free play as well as organized sports, should be carefully considered because resistance training adds to the chronic, repetitive stress placed on the young musculoskeletal system. Some children with a relatively immature musculoskeletal system may not be able to tolerate the same amount of exercise that most of their peers in the same athletic program can tolerate.

Their biologic uniqueness results in stress failure syndromes manifested by a variety of conditions including tendinitis, stress fractures, and juvenile osteochondritis desiccans (28, 94).

Because of the interindividual variability in stress tolerance, each child must be treated as an individual and observed for signs of incipient stress failure syndromes that would require a modification in frequency, volume, intensity, and progression of training. Through an awareness of this variability in children of the same age in their ability to tolerate stress, many of these stress failure syndromes can be prevented.

Resistance training programs should not simply be added to children's exercise regimens, which may already include several hours of free play and sport-specific training. Rather, youth resistance training should be incorporated into a periodized conditioning program that varies in volume and intensity throughout the year (121). Correctable risk factors (e.g., muscle imbalances, inflexibility, poor physical condition) should be identified so that coaches and clinicians can address each child's specific needs. In some instances it may be necessary for young athletes to reduce their sport involvement to allow time for preparatory conditioning.

■ Psychosocial Effects

The potential impact of youth resistance training on psychosocial variables is sometimes overlooked. Data from adult studies suggest that the effects of resistance training extend beyond physical measures and include improvements in mental health and well-being (40, 42). Although it is reasonable to assume the same would be true for children who participate in resistance training programs, one must be cautious about extending such observations to children because of their psychological immaturity as compared to adults.

Data from self-reported psychometric measurements demonstrate that adults who participated in a resistance training program scored significantly higher than controls on various measures of self-concept (self-image) (74, 120, 125, 126), self-esteem (36, 87, 127), and body cathexis (feelings toward one's own body) (87). In one study (128), an inverse association between pretest measures of body cathexis, self-concept, and neuroticism, and global self-concept change, suggested that adults who began resistance training with a relatively poor body attitude tended to make the greatest improvements. A similar study (129) noted that novices reported significantly greater gains in body satisfaction than persons with previous resistance training experience.

Unfortunately, the acute program variables were not defined in many of these reports, thus the type of strength training program that will most likely enhance psychosocial well-being remains hypothetical.

Empirical evidence suggests that resistance training may have a positive influence on the psychosocial well-being of children, yet research findings are limited (7, 42, 91, 99). Clinicians have noted that the socialization and mental discipline exhibited by prepubescent boys who performed resistance training are similar to those of team-sport participants (99), and parents of prepubescents who perform resistance training have observed that their children are more likely to do their homework and household chores following resistance training (41, 137). Moreover, it was found that children's attitudes toward physical education, physical fitness, and lifelong exercise improved following a conditioning program that included resistance training (140).

One study involving untrained adolescent girls noted improvements in self-efficacy and general self-esteem following a 12-week resistance training program (70). Conversely, an 8-week study of prepubescent boys and girls who participated in resistance training reported no significant changes in self-concept or self-efficacy, although ceiling effects in both measures may have precluded significant results (47). These findings support the contention that the psychological benefits of resistance training may depend on the intensity and duration of training, and may be most apparent in children who begin training with below average measures of strength and psychosocial well-being (47). There is not enough scientific evidence to state unequivocally that resistance training will have a positive effect on the psychosocial well-being of prepubescents and adolescents.

Participation in physical activity can enhance character development and psychological well-being (26, 59). If appropriate resistance training guidelines are followed, and if children are encouraged to embrace self-improvement and feel good about their performances, the positive psychosocial effects of resistance training programs may indeed be comparable to those of other sports and recreational activities (42). Conversely, overzealous coaching and excessive pressure to perform at a level beyond one's capabilities can have a negative effect on some children who are emotionally and psychologically vulnerable (26, 59).

■ Health Related Benefits

Children should be encouraged to participate in daily physical activity in order to establish good health

habits at an early age (57, 110). Ideally, at least half of a child's free time should be devoted to sports and other physical activities in order to improve the fitness components of strength, endurance, flexibility, and agility. Although good health habits developed during childhood do not always track into adulthood, their potential positive influence on the adult lifestyle should be recognized. In order to realize all of the potential physical and psychosocial health benefits of youth resistance training, coaches and instructors must appreciate the psychological immaturity and physical uniqueness of children.

Health should not be defined as the mere absence of disease, yet an operational definition of health, as applied to children, is elusive because there is no real consensus on the behaviors required to achieve optimal health. Nevertheless, behaviors and exposures that increase the acquisition of health associated characteristics (e.g., improvements in growth pattern, blood lipid profile, blood pressure, body composition, and psychological well-being) may be deemed desirable for children, whereas overall health may be reduced if unfavorable degrees of these characteristics are present. The relative impact of differing combinations of health associated characteristics on children's overall health is not known. Although it is tempting to extrapolate the findings from adult studies to children, it may be that what is deemed healthy for an adult may not necessarily be so for a child.

There is limited support in the current research for the utility of youth resistance training in enhancing health associated characteristics. Nevertheless, there is some support for the contention that children's overall health is likely to improve rather than be adversely affected by resistance training.

Although the acute blood pressure response to lifting weights is reportedly similar between children and adults (92), blackouts and chronic hypertension—which have been reported in adult competitive weightlifters (30) as well as adult athletes who over-train (71)—have not been reported in prepubescents (46, 99, 111) or adolescents (63) following short-term (8 to 12 weeks) resistance training programs. Submaximal resistance training has in fact been shown to decrease the blood pressure of hypertensive adolescents (63), and low intensity/high repetition resistance training has been recommended for hypertensive adolescents who wish to undertake this type of training (143).

Despite the old myth that resistance training will stunt the statural growth of children, current observations indicate that youth resistance training (up to 20 weeks) will not have an adverse effect on growth

patterns (46, 98, 107, 114, 133, 137). If age-specific physical activity guidelines are followed and nutritional recommendations (e.g., adequate calcium) are adhered to, physical activity, including resistance training, may have a favorable influence on growth at any stage of development but will not affect the genotypic maximum (8, 39).

Resistance training has been found to enhance the bone mineral density of adults (1, 62, 116), and some evidence, though not all (18), suggests that resistance training may be an effective stimulus for bone mineralization in children (31, 32, 81, 132). It seems prudent for children who are at risk for osteopenia or osteoporosis to incorporate some form of resistance training into their exercise regimen. Although peak bone mass is strongly influenced by genetics, nonhereditary factors such as exercise and proper nutrition can be important osteogenic stimuli (117). Too much exercise, however, may actually result in bone loss and an increased susceptibility to stress fractures (25, 134).

Since the prevalence of childhood obesity in the U.S. continues to increase (58), the potential influence of resistance training on body composition is an important health concern. A few studies on prepubescents have reported a decrease in fatness, as measured by skinfold thickness, following resistance training (46, 107, 114). However, a majority of the data suggests that resistance training will not significantly affect the body composition of prepubescents (85, 95, 98, 111, 133, 137). The body composition of adolescent boys is more likely to be influenced by resistance training because of hormonal influences on muscle hypertrophy.

Although the issue of childhood obesity is complex (105), resistance training at moderate intensities and high repetitions, combined with aerobic exercise, may be the ideal solution for long-term fat loss and weight maintenance. Resistance training programs characterized by moderate loads and a high number of repetitions have also been found to have a favorable influence on the blood lipid profile of prepubescents (138), and similar findings have been reported in adolescents (52).

As noted earlier, psychosocial benefits may be realized from youth resistance training programs (42). If the program is well designed and supervised by qualified adults who appreciate the importance of having fun, resistance training may offer socialization and related benefits that are comparable to those gained from participation in team sports. The instructional period affords coaches the opportunity to educate children about the benefits of a healthy

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lifestyle through regular training, good nutrition, and adequate sleep; it also increases the likelihood that children will master new skills. Youth resistance training provides an opportunity for virtually all participants to be continually challenged and to feel good about their successes.

Furthermore, if the program is appropriate for the child's age and maturation, it may foster favorable attitudes toward fitness and lifelong exercise. Young athletes who increase their strength by resistance training seem better prepared to tolerate the sometimes forceful demands imposed on their immature musculoskeletal systems. Although speculative, children who are stronger and more powerful are more likely to succeed in sports, and therefore are more inclined to value the physical and psychosocial benefits of lifelong exercise. Conversely, inappropriate coaching methods and unethical training practices may lead to the abuse of performance enhancing drugs (45, 86, 122), eating disorders (43), burn-out (59), and other adverse consequences (124).

There is not enough evidence to determine the extent of improvements, if any, in subjective energy level, sleep patterns, emotional maturity, immune function, nutritional status, or cognitive performance. Probably these characteristics would either be favorably altered or at least not unfavorably influenced by resistance training, provided the program were properly designed, fun for children, and rewarding.

■ Recommended Youth Resistance Training Guidelines

Prerequisite to the development and administration of safe and effective youth resistance training programs is an understanding of established training principles and an appreciation for the physical and emotional maturity level of children. In order to begin resistance training, a child must be mentally and emotionally ready to comply with coaching instructions and undergo the stress of a training program. In general, if a child is ready for participation in sports, he or she is ready for some type of resistance training. A medical examination is desirable, though not mandatory, for apparently healthy children. But a medical examination is recommended for children with known or suspected health problems.

Since the goals of a resistance training program are specific to each child's needs, resistance training programs will differ. Various combinations of program variables have proven safe and effective for children as long as program developers use scientific information, established training principles, and common sense (77, 102). All exercises must be

performed using the correct technique, and the ratio of resistance training to rest periods must be carefully monitored to ensure that each child is tolerating the prescribed regimen.

The ideal approach is to incorporate resistance training into a periodized conditioning program in which the volume and intensity of training changes throughout the year. Instructors must recognize the different maturation rates of children and be aware of the genetic predispositions for physical development. Children must not be treated as miniature adults, nor should adult exercise guidelines and training philosophies be imposed on children.

Trained fitness professionals must supervise every exercise session and must have a thorough understanding of youth resistance training and safety procedures. Professional certification in the area of strength and conditioning is highly desirable and is available through the NSCA. An instructor-to-child ratio of 1 to 10 is acceptable; however, additional supervision may be needed during the first few weeks of the program. Information should be presented to children in a way that is appropriate for their level of understanding. Children should be encouraged to ask questions and freely state their concerns about the program. Charts, posters, and workout cards that promote proper exercise technique and realistic expectations are helpful.

Basic education regarding realistic goals, individual needs, and expected outcomes should be part of the resistance training program. Moreover, the exercise sessions provide an opportunity to teach children about their bodies and the importance of proper nutrition and regular exercise. Instead of competing against each other, children should be encouraged to embrace self-improvement and feel good about their performances, for example the ability to perform a multijoint lift. The focus of the program should be on proper lifting technique and having fun.

Different resistance training modalities have proven to be equally safe and effective for children. Although resistance training equipment is required for many exercises, body-weight-resisted and partner-resisted exercises are viable alternatives. Pads and boards may be used to modify certain types of adult-size equipment; however, some exercise machines may not fit a child's limb length. Child-size weight machines are now available from several manufacturers.

Factors such as safety, cost, construction, weight stack increments, and proper fit should be considered when evaluating resistance training equipment

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for children. In terms of gains in strength/power and motor performance in children, the quality of supervision and the design of the resistance training program appear to be more important than the type of equipment used.

The following guidelines for designing and implementing youth resistance training programs are recommended:

- Each child should be physiologically and psychologically ready to participate in a resistance training program.
- Children should have realistic expectations; remind them it takes time to get in shape and learn a new skill.
- The exercise environment should be safe and free of hazards.
- The exercise session should include 5 to 10 minutes of general warm-up exercises such as low intensity aerobics and stretching, followed by one or more light to moderate specific warm-up sets on the chosen resistance exercises.
- The exercise equipment should be in good repair and properly sized to fit each child.
- All training sessions should be closely supervised by experienced fitness professionals.
- All children should receive careful and competent instruction regarding exercise technique, training guidelines, and spotting procedures.
- All children should be taught weight room etiquette such as returning weights to the proper place and respecting physical differences.
- The session should start with one set of several upper and lower body exercises that focus on the major muscle groups. Single- and multijoint exercises should be included in the training program. Beginning with relatively light loads (e.g., 12- to 15-RM) will allow for appropriate adjustments to be made.
- The resistance should be increased gradually as strength improves. A 5 to 10% increase in overall load is appropriate for most children.
- Progression may also be achieved by gradually increasing the number of sets, exercises, and training sessions per week. Depending on the goal of the training program (i.e., strength or local muscular endurance), 1 to 3 sets of 6 to 15 reps performed on 2 or 3 nonconsecutive days a week is recommended. Throughout the program, one should observe each child's physical and mental ability to tolerate the workout.
- Each child should feel comfortable with the program and should look forward to the next workout. If a child has concerns or problems with a training program, the fitness professional is expected to make the appropriate modifications.
- Specific multijoint structural exercises (bench press, squats, leg press) may be introduced based on individual needs and competencies. When performing any new exercise, the child should start with a relatively light weight, or even a broomstick, in order to learn the correct technique with minimal muscle soreness.
- Advanced multijoint structural exercises such as Olympic-style lifts and modified cleans, pulls, and presses may be incorporated into the program, provided that appropriate loads are used and the focus remains on proper form. The purpose of teaching advanced multijoint lifts to children should be to develop neuromuscular coordination and skill technique. Coaching guidelines on resistance training and weightlifting exercises are available through the NSCA.
- A child who seems anxious about trying a new exercise should be allowed to watch a demonstration of it. Teach the child how to perform the exercise, and listen to each child's concerns.
- The concept of periodization should be incorporated into a child's training program by systematically varying the resistance training program throughout the year.
- Competition between children should be discouraged; instead, focus on participation with lots of movement and positive reinforcement.
- One should make sure each child enjoys resistance training and is having fun; do not force a child to participate in a resistance training program.
- Instructors and parents should be good role models. Showing support and encouragement will help maintain interest.
- Children should be encouraged to drink plenty of fluids before, during, and after exercise.
- Children should be encouraged to participate in a variety of sports and activities.

Age-specific training guidelines, program variations, and competent supervision will make resistance training programs safe, effective, and fun for children. Instructors must understand the physical and emotional uniqueness of children, and in turn, children must appreciate the benefits and risks asso-

ciated with resistance training. Although the needs, goals, and interests of children will continually change, resistance training should be considered a safe and effective component of youth fitness programs.

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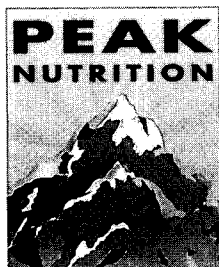
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