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Strength and Conditioning in the Young Athlete for Long-Term Athletic Development

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Abstract

The safety and efficacy of youth strength and conditioning programs depend on proper instruction, coaching, and supervision. Types of training include bodyweight strengthening, resistance bands, medicine balls and weights, agility, plyometrics, and cardiovascular exercise. These should be preceded by a proper warm up using a combination of static stretching, self-myofascial release, dynamic warm-ups, and sport-specific warm-ups. Coaches and trainers should consider the athlete's age, maturity level, cognitive ability, puberty status, sport volume, and readiness levels in designing and supervising strength and conditioning programs. This review article covers the latest evidence supporting training to improve movement skills and promote long-term athletic development, while also preventing injury, for young athletes.

Keywords

young athlete, youth sports performance, pediatric strength training, strength and conditioning, adolescent sports

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Introduction

Youth of all ages are playing competitive, organized sports and participating in other physical activities at increasing rates [17]. They therefore face increasing pressures that can lead to greater risk for sports-related injuries [33]. Strength and conditioning programs that involve appropriate exercise selection, precautions, and guidance are critical to the physical and psychological health and wellness of today's young athletes.

Yet many factors can impede a child's participation in such a program, including a lack of formal training for coaches and too few professionals specializing in training young athletes. Misunderstandings about strength and conditioning among parents may include myths such as "Strength training will stunt my child's growth," "I don't want my daughter to get bulky," or "My kids are too busy with sports to work out." Online or mass-produced information can be too scientific (anatomical or mechanistic) or in-depth (exercise selection, programming, reps, sets) for parents and children to comprehend or too broad and unstructured for pediatricians to put into practice.

Still, professionals in all areas of youth sports believe strength and conditioning programs benefit young people by solidifying long-term athletic development and improving bone and muscle health, hormone regulation, body composition, body awareness, movement control, and longevity in sport through injury prevention. Resistance training is safe and effective for children as early as elementary school. Professional organizations differ only on what age weightlifting can begin (Table 1) [6,8,9,11,19,25,32]. Otherwise, consensus statements universally recommend strength and conditioning training for youth, with supervision, that should include warm up and cool down, with a focus on technique, power, and agility.

Developing a safe strength and conditioning program for young athletes can seem overly complicated. This review aims to simplify by describing what is known about

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Table 1. Recommended ages to begin youth strength and conditioning.

	ACSM	NASM	NSCA	ACE	AAP	UKSCA	ASCA
Minimum age (years)	School	6	6	7 or 8	5	School	6
Age for resistance (years)	7	6	School	7 or 8	School	School	6/school
Age for weightlifting (years)	-	-	11	-	-	11	-

ACSM American College of Sports Medicine, *NASM* National Academy of Sports Medicine, *NSCA* National Strength and Conditioning Association, *ACE* American Council on Exercise, *AAP* American Academy of Pediatrics, *UKSCA* United Kingdom Strength & Conditioning Association, *ASCA* Australian Strength and Conditioning Association.

Table 2. Programming per age group and type.

	2-6 years	7-9 years	10-11 years	12-18 years
Type of resistance	Body weight (BW)	BW/isometrics	Bands, weights, medicine balls, dowels	Heavier loads + bands, barbell, dumbbell, kettlebell, medicine ball
Examples	Animals/game and play oriented	Athletic/foundational movement mechanics: push, pull, squat, lunge, jump, ready position, balance	Strength, power, agility (reactionary)	Weightlifting, powerlifting, power, agility (strategic)
Cueing	External	External	External and body awareness (mimicking)	External/internal
Cue example	"Crawl like a bear"	"Be stiff as a surfboard" "Land quiet like a ninja"	"Push your hips back like sitting into a chair"	"Push the ground away" "Lead with your hips"

effective youth strength and conditioning programs for all ages of development.

Establishing Safety

Possible injuries youth can sustain while exercising include growth plate injuries, acute or long-term stress fractures, sprains, strains, ruptures, and spine injuries such as spondylolysis. Injuries can be associated with overuse, improper technique, or excessive load. Safety also encompasses psychological and psychosocial well-being, as well as fatigue and energy availability.

Age matters. The differences between a 6-year-old and a 17-year-old encompass more than size and behavior. In fact, the way a young person expresses themself, understands cueing and communication, and reacts to feedback and coaching depends on mental maturity and brain development. Therefore, coaching that applies integrative neuromuscular training models geared to developmental stage is the most important way to reduce sports injury risk [17]. Cueing, directions, and exercise type that match a child's age, maturity, and cognition (as established by Piaget's developmental stages) set the stage for athletic development and lifetime participation in physical fitness. Understanding where the child fits in this spectrum can improve the success of programming (Table 2).

Overuse injuries can be persistent and long lasting. Injuries such as little league elbow/medial epicondyle apophysitis can be traced back to the number of overhand throws, improper mechanics, and lack of rest and recovery. In young athletes, the spine is also at risk for overuse injuries. Spondylolysis, a common sports-related injury in a growing child, involves unilateral or bilateral pain with lumbar extension, rotation, throwing, and jumping; diagnosis requires imaging, not just clinical presentation. For most young athletes, conservative, nonsurgical treatments including physical therapy have been shown to allow for return to sport [14]. Spine injuries can be prevented through strength and conditioning that focuses on core strength, movement patterns, improving flexibility, with rest and recovery.

Volume is the key factor in overuse injuries—too many days throwing, too many pitches, too many foot strikes, or too many consecutive days in the gym. Volume must be monitored by a trained professional or coach. For example, the Little League [18] breaks down the appropriate number of pitches per week for young athletes according to age group. Most overuse injuries can be prevented by instruction in rest/recovery, strength and conditioning, and mechanics. In cases of injury, addressing mechanics, weakness, structured return, and volume control plays a large role in return to sport without recurrence. Understanding that throwing mechanics for a baseball pitcher are similar to those of players in other positions should help to address prevention techniques.

When it comes to the spine, it is important to consider the athlete's sport and the demands of movements such as a back handspring, which requires lumbar extension, rotation,

Table 3. Warm-up styles and performance outcomes.

	Warm-up styles	Tested	Conclusion
Škarabot et al [28]	SMR vs SMR + SS	Ankle mobility / ROM	More improvement SMR + SS.
Merino-Marban et al [21]	DWU vs SS v. None	Single leg long jump	Significant improvement w/ DWU, decrease with SS and control group.
Taylor et al [30]	SS vs SS + DWU	Sprint	Decreased performance with SS; DWU voided those negative effects.
Young and Behm [31]	Run/Jog + SWU vs run + SS vs Run only	Peak jump height, peak force, rate of force developed, drop jump height, contact time	Run + SWU increased explosive force and jumping performance.
Behm and Chaouachi [4]	Sub maximum aerobics + DWU + SWU vs SS only	Performance impairments	DWU + SWU + submaxim reduced risk of impairment over just SS prior to performance.
Donti et al [7]	SS on acute/long-term ROM	Countermovement jumps in gymnasts	Not beneficial to the CJM but ROM was maintained both acutely and over long-term period.

SMR self-myofascial release, *SS* static stretching, *SWU* stretch warm-up, *DWU* dynamic warm-up, *CJM* countermovement jump, *ROM* range of motion.

and a landing with a lot of power and torque. This maneuver is one piece of the athlete's training. If the athlete is also in the weight room back squatting or overhead pressing, they are then training in the same position, but with load. The ideal approach is for the athlete and coach to monitor resistance and intensity throughout strength training and skill development. Using percentages of repetition maximum (RM) and balancing which days the athlete is performing a skill should help reduce the risk of an overuse injury.

If a child is too young to grasp or listen to instruction, there can be a high risk of injury [17]. Other high-risk situations include a loud swim class, multiple groups of children in the same area doing different things, multiple children in a weight room lifting at the same time, or too many children per coach/instructor. Most organizations suggest 6 years old as a starting age for resistance training, unless the child has expressed the inability to listen and follow instructions [12]. According to the American Academy of Pediatrics, the ability to follow instructions begins to develop at around 4 years old [12,17]; when following instructions proves challenging, resistance training may not be the best option. Live action play, mimicking, pretending, follow the leader, game situations, and specific athletic position training through play may be best suited to increase physical activity without placing a young child at risk.

Coaches and trainers must be aware of relevant underlying health conditions. Children with conditions such as congenital heart disease or severe asthma may need to avoid certain types of resistance training exercises [9]. Overweight or obese children may need to focus on cardiovascular exercise and weight loss prior to beginning a resistance training program [10].

Warm up, necessary prior to exercise or sport, increases core and muscle temperature and muscle firing rates, improves flexibility and mobility, and reduces risk of injury before fast-paced, explosive maneuvers. Modalities include foam rolling, static stretching, dynamic warm-ups, and sport-specific movements. Experienced athletes with better cardiovascular endurance may add a low-aerobic warm-up routine with dynamic warm-ups and sport-specific warm-up to decrease chances of impairments during sport [4].

Most studies of foam rolling and other self-myofascial release techniques are in adult or collegiate populations [28]. None have shown negative effects that would deter use on young athletes. Benefits include increased joint range of motion and overall flexibility. Studies have found that when static stretching is coupled with self-myofascial release, dynamic warm-ups or sport-specific warm up, athletic performance is significantly better than static stretching alone or no warm-up at all (Table 3) [4,7,21,28,30,31].

Resistance Training

Resistance training may require more neural processing than young children have. Therefore, the choice of activity and exercise depends on age. Children, like adults, have goals and interests. Those interested in athletics benefit from exercises that improve skills such as running, jumping, or throwing [12]. Those more interested in improving fitness benefit from exercises targeting various muscle groups [10]. A meta-analysis provides strong evidence that young people of all ages gain muscle strength in a linear relationship with concentric exercises that is not dependent on age and maturity status [5]. A significant boost in muscle strength development does not appear to occur with puberty.

Children as young as 5 years old can perform concentric, isometric, and eccentric contractions, but this ability may depend on age, sex, and level of physical activity [9].

A study in children with cerebral palsy found they could perform both concentric and eccentric contractions during a leg press exercise; the older children could generate more force during both types of contractions than their younger counterparts [27], showing some advantage for pubertal and biomechanical enhancements with age. Unfortunately, when assessing potential differences based on sex, we found that most study subjects have been male. Mohtadi et al [22] found prepubescent boys could perform both concentric and eccentric contractions during a knee extension exercise; boys who reported more physical activity had greater strength during both types of contractions than less-active boys.

Isometric exercises can improve team bonding, enhance neural adaptations, perfect positioning, and increase intensity through lactate build up and the "burn" sensation. Faigenbaum et al [13] showed that isometric exercises such as planks and wall pushes improved strength in 10-to-12-year-olds due to increased motor unit recruitment, firing rate, and movement efficiency. A form of resistance training, isometrics are a safe way for less-experienced children to improve muscle strength [15] at home, a park, or school, in individual or group settings [20].

Squats, lunges, push-ups, pull-ups, and other body-weight exercises are safe, effective, and scalable and can be taught virtually without specialized equipment. Using resistance bands can increase exercise intensity in biceps curls, leg extensions, and shoulder presses but requires cueing and cognitive awareness [9]. Medicine ball exercises such as overhead throws, chest passes, rotational tosses, and rolls can build fun into workouts [6] and improve awareness of a child's own strength and cause and effect.

Olympic weightlifting is an increasingly popular sport in children involving 2 lifts, the snatch and the clean and jerk. While there has been concern about the safety of Olympic weightlifting for children, the American Academy of Pediatrics states that strength training can be beneficial for children as young as 7 years old, as long as they are physically and emotionally ready [6]. The International Weightlifting Federation (IWF) has developed guidelines for youth weightlifting that include proper technique, equipment, and supervision [1]. A recent study found that Olympic weightlifting can be safe for children if they are properly trained and supervised and that weightlifting posed a lower risk of injury than other sports, such as football or basketball [9].

A regular resistance exercise program can strengthen children's bones and muscles. Bone growth typically peaks between 20 and 30 years of age [3]. Regular physical activity can improve bone density, increase muscle mass, and enhance overall physical fitness in children [16]. Engaging in weightbearing activities such as running and jumping can promote bone health and reduce the risk of osteoporosis later in life [3]. In addition, resistance training can help build muscle strength and endurance in children [10]. Improved bone density resulting from resistance training programs can benefit long-term athletic development.

Plyometrics and Speed

Youth conditioning programs aim to make participants faster, quicker, and more explosive. This means teaching them how to maneuver a skip, build leg turnover into a run, apply angles and explosive feet for sprinting, and load and land a jump. Prepubescent children tend to rely on aerobic metabolism; with maturity anerobic systems are used more efficiently when training [20]. A learning progression of plyometric exercises based on age, ability, instructional understanding, and body maturity might involve, for example, ages 4 to 6 years, skips; ages 7 to 9, squat jumps; ages 10 to 11, countermovement jumps; ages 12 to 18, vertical jumps.

Oliver et al [23] determined that growth and maturation, motor skill acquisition, and biomechanical factors are specific considerations for successful plyometric training in youth. The progression from prepubertal to college-level athletics comes with biomechanical changes such as height and weight spurts that alter the center of gravity and shift fat/lean body mass. Foot and limb growth create longer arms that require careful consideration in developing higher-level movement programs. Puberty initiates physiologic changes in the muscle–tendon relationship and in anaerobic metabolism. By age 12, children have reached 95% of their adult limb length [23], with a potential for faster movement, but they need to learn control. Varying levels of maturity in adolescence affect how drills are cued and skills are taught.

Rumpf et al [24] determined that prepubescent children responded well to training for neural adaptations, demonstrating improved performance following neural adaptations and plyometrics with their morphological changes. Postpubertal children responded best to structured strength programming to supplement their speed training. Prepubescent athletes require exercises that challenge coordination, balance, and spatial awareness, best achieved through a controlled environment (games or obstacle courses). Neural adaptations are tested by introducing fine motor skills (catching, chasing, or grabbing drills) often with collaborative teamwork. Pubertal athletes require advanced movements (hopping and lunging).

Owing to growth spurts, repetition in plyometrics is more beneficial than sport-specific drills in helping pubertal athletes master new limb length and mass. Postpubertal athletes benefit from a progressive strength program which often yields success. The crossover effect of gains in baseline strength can imply significant changes in athletic skill; for example, mastering barbell back squats at 80% 1 RM may allow for significant force production in a sport-specific vertical jump movement.

A structured program requires a progression of neural adaptations for greater central nervous system firing to improve movement capacity and force necessary for success in sport. As athletes age, strength and plyometric work improves ground-reaction force production that allows higher-level movement. As athletes reach puberty, focusing on strength and peak velocity with body weight and increasing volume of work and power output in the horizontal plane improves sprint economy and performance. Progressive load in both volume and stimulus in strength and plyometric training are essential to maintaining movement skill while also increasing force and power potential.

Nutrition, Hydration, and Rest

Teaching young athletes what to eat and drink prior to, during, and after training helps their bodies replace electrolytes and proteins lost with sweating and muscle catabolism. Timing is important; it takes time to hydrate and replenish electrolytes. Unfortunately, there are limited data on the effect of dietary manipulations in children. The primary concern is nutrition for growth, maturation, and cognitive development. Activity beyond that of a typical day requires a commensurate increase in nutrition [29].

Sleep is an essential factor in cognitive development. Santiago et al [26] found improvements in sleep quality and duration in adolescents participating in a 12-week strength training program that consisted of 3 days per week of 55 mins with 3 sets of 10 to 12 reps per exercise.

Conclusion

There is a large body of knowledge regarding the safety and efficacy of youth resistance training, provided that there is proper instruction, coaching, and supervision [2]. In establishing a training program, it is important to consider age, maturity level, cognitive ability, puberty status, sport volume, as well as intensity and readiness levels. This will help to prevent injuries and to improve consistency, movement skills, and long-term athletic development. Research to date indicates that there are no disadvantages or concerns for youth, including children as young as 5 years old, to participate in properly designed and supervised strength and conditioning programming.

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Human/Animal Rights

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Informed Consent

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Required Author Forms

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