National Strength and Conditioning Association Position Statement on Long-Term Athletic Development

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Abstract

Lloyd, RS, Cronin, JB, Faigenbaum, AD, Haff, GG, Howard, R, Kraemer, WJ, Micheli, LJ, Myer, GD, and Oliver, JL. National Strength and Conditioning Association position statement on long-term athletic development. *J Strength Cond Res* 30(6): 1491–1509, 2016—There has recently been a growing interest in long-term athletic development for youth. Because of their unique physical, psychological, and social differences, children and adolescents should engage in appropriately prescribed exercise programs that promote physical development to prevent injury and enhance fitness behaviors that can be retained later in life. Irrespective of whether a child is involved in organized sport or engages in recreational physical activity, there remains a need to adopt a structured, logical, and evidence-based approach to the long-term development of athleticism. This is of particular importance considering the alarmingly high number of youth who fail to meet global physical activity recommendations and consequently present with negative health profiles. However, appropriate exercise prescription is also crucial for those young athletes who are physically underprepared and at risk of overuse injury because of high volumes of competition and an absence of preparatory conditioning. Whether the child accumulates *insufficient* or *excessive* amounts of exercise, or falls somewhere between these opposing ends of the spectrum, it is generally accepted that the young bodies of modern day youth are often ill-prepared to tolerate the rigors of sports or physical activity. All youth should engage in regular physical activity and thus should be viewed as "athletes" and afforded the opportunity to enhance athleticism in an individualized, holistic, and child-centered manner. Because of emerging interest in long-term athletic development, an authorship team was tasked on behalf of the National Strength and Conditioning Association (NSCA) to critically synthesize existing literature and current practices within the field and to compose a relevant position statement. This document was subsequently reviewed and formally ratified by the NSCA Board of Directors. A list of 10 pillars of successful long-term athletic development are presented, which summarize the key recommendations detailed within the position statement. With these pillars in place, it is believed that the NSCA can (a) help foster a more unified and holistic approach to long-term athletic development, (b) promote the benefits of a lifetime of healthy physical activity, and (c) prevent and/or minimize injuries from sports participation for all boys and girls.

Key Words long-term athlete development, youth physical development, children, adolescents, health, fitness

Operational Terms

Throughout this position statement, the following operational terms are defined as given below:

- *Athleticism* is the ability to repeatedly perform a range of movements with precision and confidence in a variety of environments, which require competent levels of motor skills, strength, power, speed, agility, balance, coordination, and endurance.

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- The term *long-term athletic development* refers to the habitual development of "athleticism" over time to improve health and fitness, enhance physical performance, reduce the relative risk of injury, and develop the confidence and competence of all youth.
- The terms *youth* and *young athletes* represent both children (up to the approximate age of 11 years in girls and 13 years in boys) and adolescents (typically including girls aged 12–18 years and boys aged 14–18 years).
- *Growth* is the most significant biological activity during the first 2 decades of life and is defined as an increase in the size attained by specific parts of the body, or the body as a whole.
- *Maturation* is defined as progress toward a mature state and varies in timing, tempo, and magnitude between different bodily systems.
- A *qualified professional* possesses (a) an appropriate understanding of pediatric exercise science, exercise prescription, technique evaluation, and testing methods, (b) relevant coaching experience and a strong pedagogical background, and (c) a recognized strength and conditioning qualification, for example, the Certified Strength and Conditioning Specialist (CSCS) certification.

Introduction

In an address at the University of Pennsylvania in 1940, the 32nd President of the United States, Franklin D. Roosevelt, delivered the adage "We cannot always build the future for our youth, but we can build our youth for the future." Conceptually, this statement is a suitable philosophy for long-term athletic development. Ultimately, it is impossible to truly determine whether a child will be involved in elite-level sport or simply choose to engage in recreational physical activity later in life; however, it is imperative that all children learn how and why various types of physical conditioning are important to suitably prepare them for the physical and psychological demands of a lifetime of sport and physical activity. Although the development of athleticism has traditionally been viewed as a goal for aspiring "young athletes," it is crucial that strength and conditioning coaches, personal trainers, teachers, parents, and medical professionals adopt a systematic approach to long-term athletic development for youth of all ages, abilities, and aspirations (143). A list of the pillars of successful long-term athletic development is provided in Table 1.

1. Long-Term Athletic Development Pathways Should Accommodate for the Highly Individualized and Nonlinear Nature of the Growth and Development of Youth

It is commonly stated that "children are not miniature adults" and because of their immature physiological and psychosocial state, they should be prescribed appropriate training programs that commensurate with their technical ability and stage of development (145). Children's anatomy and physiology differs from that of adolescents, which in turn is different from the physiology of adults. Clear differences between children and adolescents/adults exist in muscle structure (133,193), size (62,139), activation patterns (61,62,198,259), and function (77,262). These differences will typically predispose children to reduced force-producing or force-attenuating capabilities, which will have implications for absolute measures of physical performance and relative risk of injury. Additionally, it is clear that children's metabolic profile is more conducive to oxidative metabolism (211) and recovery rates from high-intensity exercise are shorter in youth than in adults (212,250). This suggests that aerobic and anaerobic exercise thresholds will likely vary according to the stage of development. Combined, these examples underlie the potential age- or maturity-related effects on differential physiology between youth and adults. Notwithstanding other age-related and/or maturity-related differences in physiology (e.g., skeletal, cardiovascular, respiratory, or endocrine systems), practitioners must be cognizant of the fact that these systems will develop during childhood and adolescence at different rates and in a nonlinear manner (157). This variance in physical development is most notable when comparing a group of children of the same chronological age (23,145,154,156), whereby individuals of the same chronological age can differ markedly with respect to biological maturity (14,145,157). Biological maturation reflects the process of progressing toward a mature state, and varies in timing and tempo, and between different systems within the body (22). Significant interindividual variance exists for the extent (magnitude of change), timing (onset of change), and tempo (rate of change) of biological maturation. In addition to these developmental incongruities among youth, the manner in which they respond to, and recover from, training is likely to differ between youth of the same age or maturation status (5,15,16,147,219). Indeed, a real challenge for sport and exercise scientists and practitioners working with youth is to determine whether changes in performance are mediated from training-induced or growth-related adaptations.

Effects of Sport and Physical Activity on Growth and Development. Physically active children will typically outperform those who are inactive in most indices of physical performance (155). Being inactive is associated with a high probability of being overweight or obese during the growing years (179,253). Therefore, physical activity, exercise, and sport should be viewed as key preventive treatments for unfavorable weight status and an important precursor for healthy growth and development (75,76,183). There exists a positive relationship between motor skill competence and physical activity across childhood (214). Therefore, it is essential that all youth be encouraged to enhance athleticism from an early age by engaging in multifaceted training inclusive of a range of different training modes (142). Previous misconceptions regarding the impact of physical training on growth and development

TABLE 1. Ten pillars for successful long-term athletic development.

No.	Description
1.	Long-term athletic development pathways should accommodate for the highly individualized and non-linear nature of the growth and development of youth.
2.	Youth of all ages, abilities and aspirations should engage in long-term athletic development programs that promote both physical fitness and psychosocial wellbeing.
3.	All youth should be encouraged to enhance physical fitness from early childhood, with a primary focus on motor skill and muscular strength development.
4.	Long-term athletic development pathways should encourage an early sampling approach for youth that promotes and enhances a broad range of motor skills.
5.	Health and wellbeing of the child should always be the central tenet of long-term athletic development programs.
6.	Youth should participate in physical conditioning that helps reduce the risk of injury to ensure their on-going participation in long-term athletic development programs.
7.	Long-term athletic development programs should provide all youth with a range of training modes to enhance both health- and skill-related components of fitness.
8.	Practitioners should use relevant monitoring and assessment tools as part of a long-term athletic development strategy.
9.	Practitioners working with youth should systematically progress and individualize training programs for successful long-term athletic development.
10.	Qualified professionals and sound pedagogical approaches are fundamental to the success of long-term athletic development programs.

trajectories are not supported with literature, especially as data are often correlational and cross-sectional in nature (22,156). Although fears previously existed surrounding the effect of physical training on eventual growth of youth (especially in sports such as gymnastics), evidence now indicates that well-supervised physical training does not impair the development of secondary sex characteristics (153), does not delay age at menarche (160), and does not restrict eventual growth height (22,152). Moreover, when rest and training are prescribed systematically, moderate-to-high intensity exercise is needed to help bone mineral accrual during childhood and adolescence (3,13,87,88,116,118,267), which is of great benefit for long-term skeletal health.

Owing to the unique physiology of children, it is clear that practitioners working with youth require a sound understanding of pediatric exercise science to (a) prescribe training programs that are commensurate with the needs and abilities of the individual, (b) distinguish between training-induced and growth-related adaptations in performance (either positive or negative), and (c) understand the manner in which growth, maturation, and training interact to optimize the training response and the development of athleticism.

2. Youth of All Ages, Abilities, and Aspirations Should Engage in Long-Term Athletic Development Programs That Promote Both Physical Fitness and Psychosocial Well-Being

The development of physical fitness in youth is a complex process, which involves interaction of growth, maturation, and training (5,15,16,145,219,261). Practitioners should appreciate the potential impact that other lifestyle factors will have on physical fitness development and physical activity engagement, including dietary behaviors (48,52), educational stress (159), sleep patterns (95,163), psychosocial health (24), and unrealistic external pressures from significant others such as parents or coaches (201,251). Cumulatively, all these factors can impact the engagement and enjoyment experienced by youth, adherence rates to training programs, and consequently the magnitude and rate of development of physical fitness.

Despite many factors impacting the training process of youth, there is often varying levels of understanding and a lack of coordinated planning among those personnel who are responsible for the long-term welfare and well-being of children and adolescents. With these inconsistent approaches between key personnel in mind, from a global perspective, 2 primary corollaries are evident within the pediatric literature. First, the number of youth who are physically inactive, overweight, or obese and demonstrate poor standards of physical fitness, deficient levels of muscular strength, and inadequate motor skill competency follows an unfavorable trajectory (40,44,53–55,105,107,175,194,195,220,257). Of note, the term exercise deficit disorder (EDD) has been proposed to describe a condition characterized by reduced levels of moderate-to-vigorous physical activity that negatively impact the health and well-being of youth (75,76). Importantly, children and adolescents who present with symptoms or behavioral patterns reflective of EDD should be prescribed exercise interventions geared toward the development of fundamental movement skills, foundational strength, and general athleticism (76). The prevalence of substandard athleticism in modern-day youth will not only likely increase the prevalence of overweight or obese youth (114,115) but also will increase the relative risk of injury for inactive youth who eventually engage in physical activity or sports (25). Second, a growing concern for practitioners is the number of youth reporting with sport-related injuries as a consequence of overexposure to high volumes of sport-specific training/competition in the absence of adequate rest and recovery (120). Consequently, there are an increased number of young athletes experiencing nonfunctional overreaching, overtraining, burnout, and eventual dropout from sport (57,162). Young athletes should be encouraged to participate in a variety of activities and sports, avoid year-round training for a single sport, and should be carefully monitored in a coordinated manner to prevent the risk of nonfunctional overreaching or overtraining.

Because of the multifactorial nature of physical fitness development and the current trends linked with both insufficient and excessive (specialized) amounts of physical activity, a long-term and structured approach to the development of athleticism in youth is warranted. Irrespective of the population (e.g., youth, adult, seniors), it is generally accepted that a structured training program will produce superior results than unstructured training or no training at all (206). Long-term and systematically progressed approaches to developing athleticism in youth, delivered by qualified professionals, will enable more effective control over training variables, a reduction in the risk of overtraining, and an enhanced overall adaptation in physiology and performance. Although a number of authors have previously discussed the role of long-term athletic development models in developing human performance or sporting talent (9,10,49,92,142,146), it is vital that practitioners acknowledge that the constructs of long-term athletic development are appropriate for youth of all ages and abilities (143). Although a systematic approach to the development of athleticism is required to prepare aspiring young athletes for the demands of sport (69), it is imperative that all youth, including those that are inactive, underweight, overweight, or obese are afforded the same opportunity to engage in dynamic, integrated, and evidence-based training programs that promote the development of both health and skill-related components of fitness (75,143,144,180,182).

Performance vs. Participation Pathways. Despite existing models for the long-term development of athleticism providing structure and guidance for practitioners, it should be noted that any model should not be viewed as a stringent blueprint that can be superimposed on any participant, within any environment. Rather, practitioners must ensure that wherever possible, long-term training programs are tailored to the needs of the individual and within the confines of the unique demands of the training environment. This is a pertinent factor owing to the highly individualized interaction effects of growth and maturation on the training response of youth. Regardless of the model that a child enters, it is imperative that they are able to transition between developmental pathways (143). Adolescence offers a time in which young athletes are more likely to drop out of competitive sport (85), but some individuals will subsequently remain involved in sport or physical activity at a recreational level. Similarly, an adolescent may be identified by a sporting organization as a talented athlete who has previously only participated in recreational physical activities. In either event, the adolescent should be supported from a holistic perspective. Physically, they should be prescribed suitable training that prepares them for the demands of their sport or physical activity while enabling them to achieve recommended exposure to daily physical activity (264). They should also be provided with relevant support that encourages the development of a positive sense of self-worth, self-confidence, motivation, and enjoyment to foster a lifetime of engagement in sport and physical activity.

3. All Youth Should Be Encouraged to Enhance Physical Fitness From Early Childhood, With a Primary Focus on Motor Skill and Muscular Strength Development

Whether a child is engaged in competitive sport or simply participates in recreational physical activity, a common philosophy of long-term athletic development models is that engagement in physical activity during early childhood is vital (143). The developmental time frame of brain maturation is associated with a heightened degree of neural plasticity during childhood (37,38,181,215). This stage of development involves the process of pruning and an overall strengthening of the synaptic pathways (148,237,238,241) and provides an opportunity to take advantage of the motor skill potential of children. Existing models of long-term athletic development indicate that training foci during the initial stages of childhood should be based on the acquisition of rudimentary and fundamental motor skills in addition to the development of foundational strength (10,39,143,146). Although correct execution of fundamental motor skills requires coordinated sequencing of multimuscle, multijoint, multiplanar movements, there will always be a requirement for complimentary force production and force attenuation. Neuromuscular coordination and force production are governed by neural activation and control, and thus it is optimal to target the development of motor skills and muscular strength at a time when the corticospinal tissue in children is highly "plastic" (188). Practitioners should not view coordination and muscular strength as separate entities but rather synergistic components of motor skill performance (39) and should therefore seek to develop both qualities during early childhood. Although youth should engage in multidimensional strength and conditioning programs that use a range of training modes to develop both health- and skill-related components of fitness, prioritizing neuromuscular training that enhances both muscular strength and motor skill prowess, starting from early childhood, is recommended for the long-term physical development of both children and adolescents (70,75,142).

For the long-term enhancement of athleticism, developing a proficient physical "vocabulary" of fundamental motor skills during early childhood should serve as the foundations on which more advanced and complex specific motor skills can be later developed (134,142,188). Specifically, fundamental motor skills encompass the ability to perform locomotive, manipulative, and stabilizing movements (149). Complimenting motor skill training with muscular strength development during early childhood is crucial because muscle strength is a key determinant of motor skill function (70). Muscular strength is strongly associated with a multitude of physical qualities in youth, for example, speed and power (45). Additionally, enhancing muscular strength using resistance training can improve physical performance (15,108,141), improve markers of health in obese and overweight youth (18,19,229–231,247), and help reduce the risk of sports-related injury (172,180,190,256). Thus, a primary aim of long-term athletic development programs should be to develop resilient, strong, and technically proficient youth, who can robustly maintain motor skill competence within the demands of any sporting or recreational activity. This philosophy is of particular importance considering recent trends in the neuromuscular fitness of youth (44,175,220). A meta-analytical review of 34 training studies showed that pre- and early-pubertal youth achieved resistance training-induced gains in motor skills that were approximately 50% greater than adolescents (15), thus highlighting the increased trainability of motor skills in children. Aside from the development of athleticism, preparatory conditioning inclusive of motor skill and muscular strength development provides an appropriate strategy for reducing the relative risk of injury for youth during sport and physical activity later in life (69,80,111,112,190). Motor skill competence, and indeed the perception of motor skill competence, is an important antecedent of physical activity during childhood (42,83,107,135,214,242) and adulthood (140,149). Cumulatively, early engagement in developmentally appropriate training during childhood is warranted for the optimization of athleticism, lifelong health and well-being, and the reduction of relative risk of injury.

Starting Age. Although there is not a single chronological age at which it is deemed acceptable for youth to formally start training, recent guidelines recommended that any child engaging in a form of resistance training is emotionally mature enough to accept and follow directions and possesses competent levels of balance and postural control (approximately 6–7 years of age) (134,141,189). However, children should engage in exploratory and deliberate play from early childhood (from birth to the age of 5–6 years) inclusive of activities designed to develop fundamental motor skills (138) and foundational levels of strength (e.g., gymnastics or similar bodyweight management activities) (143). If children are ready to engage in organized sports, they are ready to participate in developmentally appropriate strength and conditioning as part of a long-term approach to developing athleticism (189).

4. Long-Term Athletic Development Pathways Should Encourage an Early Sport Sampling Approach for Youth That Promotes and Enhances a Broad Range of Motor Skills

Sampling refers to an approach that encourages youth to engage in a variety of sports or activities and a number of positions within a given sport. Literature has stated that a sampling approach does not restrict elite sporting development, but in fact, facilitates longer sporting careers and increases the chance of sustained participation in physical activity (50). Conversely, early *specialization* refers to the concept of a child participating in year-round intensive training within a single sport or physical activity at the exclusion of others (57,265). Concerns exist regarding the adoption of an early specialization approach in youth, largely because of the inherent associations with increased risk of injury (36,78,79,104,119,120,187,192,235), the potential "blunting" of an individual's motor skill portfolio (57,144,176,186), a reduced standard of performance later in life (28,84,96,174,268), an increased risk of overtraining or dropout from sport or physical activity (4,35,151,187), and the nonguarantee of achieving elite-level performance (28,101,174).

Effects of Early Specialization on Physical Performance. Irrespective of the potential risks associated with early sport specialization, both children and adolescents are being encouraged to engage earlier in sports often because of the lure of a higher standard of performance, for example, securing national team selection, college scholarships, or professional contracts. The assumption that earlier specialization will lead to enhanced sports performance has largely been driven by the incorrect extrapolation of data examining the development of expert musicians and the proposed "10,000-hour rule" (66). The rule denotes that an individual must acquire 10,000 hours of deliberate practice to attain mastery in a given sport or activity, which could also be viewed as dedicating specific practice to the same sport or activity for 3 hours a day for 10 years. However, in a recent editorial, it was suggested that their seminal work on expert performers had been misinterpreted and that expert performance had been achieved by some with just 5,000 hours of practice (65), which is more reflective of the training volumes reported for actual sports performers (174). Consequently, practitioners should not subscribe to the hypothetical 10,000 hours rule, but instead value the *quality* of practice rather than a specific *quantity* of practice.

The early specialization approach is particularly common when young children display innate talent at a young age, leading to significant others (e.g., parents or coaches) seeking achievement by proxy distortion and going beyond normal ambition for success (251). In contrast, although it may be a common view that an accumulation of greater volumes and intensities of sport-specific practice at a young age will lead to sporting success, existing data do not support this notion, with the number of individuals transitioning from entry level to elite standard across a range of sports in a linear fashion remaining small (101). For sports measured in centimeters, grams, or seconds (e.g., track and field, swimming, or weightlifting), later specialization and exposure to lower volumes of specific practice earlier in life are significant determinants of elite performance in adulthood (174). Despite potential early accomplishments, in general, athletes who specialized at an earlier age experienced less success as they became older (174). Furthermore, athletes who did achieve elite sporting success were found to intensify their training toward the end of adolescence, leading to greater volumes of training toward early adulthood. Similarly, adopting a sampling approach and investing in multiple sports as opposed to specializing in a single sport produced improved performance in gross motor coordination and standing broad jump tests in 10- to 12-year-old boys (84). In addition, the analysis of retrospective data across a multitude of sports indicates that individuals who participated in 3 sports or more between 11 and 15 years of age were more likely to play national compared with club standard sport between 16 and 18 years (28).

Effects of Early Specialization on Injury Risk. The risks of overuse injury seem to increase as a result of early specialization due to the repetitive submaximal loading on the musculoskeletal system in the absence of sufficient recovery time for subsequent adaptation (57,239). For example, data from a sample of female youth athletes showed that those who had specialized at an earlier age had a 1.5-fold greater risk of knee-related injury (104). The authors also reported that diagnoses including patellar tendinopathy and Osgood-Schlatter disease exhibited a 4-fold increased relative risk in single-sport specialized versus multiple-sport athletes (104). In a similar study, data on 1,190 individuals showed that after accounting for age and time spent playing sport, sports-specialized training was a significant independent risk factor for acute and serious overuse injury (120).

The increased training volumes associated with early specialization are a pertinent injury risk factor for youth (119). For example, high training volumes and competitive workloads are strongly associated with an increased risk of overuse injury in adolescent baseball pitchers (200). Additionally, high volumes of weekly running mileage are significantly associated with increased risk of lower-limb injury in adolescent runners (248), whereas a high training volume was the most influential risk factor for injury in a cohort of 2,721 high school athletes across a variety of sports (216). Recently, Jayanthi et al. (120) revealed a heightened risk of injury when youth participated in more hours of sports practice per week than their number of years in age, or whereby the ratio of organized sports to free play time was in excess of 2:1. Regardless of age, existing data support the notion that youth should not train in excess of 8 months per year in a single sport (120,200), whereas the weekly training volume of 16 hours marks a threshold above which the risk of injury increases (144,187).

Overexposure to a narrow range of specific movement patterns with insufficient rest and recovery and an ensuing blunted motor skill portfolio are common links to both the reduced physical performance and higher risk of injury associated with early sport specialization. By exposing youth to different sports and activities and adopting a movement variability approach to motor skill development within different environments, they are less likely to chronically overstress specific regions of the musculoskeletal system, therefore reducing their risk of overuse injury. Adopting a movement variability philosophy will ensure that the point of force application will constantly vary; thus promoting more global whole-body adaptation, facilitating change in coordination, and reducing injury risk (12). Regarding physical performance, developing a broad spectrum of fundamental motor skills will enable more intricate and reactive global movements that are inherently witnessed in sports, physical activity, and free play to be developed (149). Qualified professionals should focus on developing a wide breadth of movement skills as opposed to a depth of mastery in a small range of skills to better enable the individual to produce effective and efficient movements in a wide range of environments and to maximize their overall athleticism.

5. Health and Well-Being of the Child Should Always Be the Central Tenet of Long-Term Athletic Development Programs

Health can be defined as "a condition of well-being free of disease or infirmity and a basic and universal human right" (227). Huppert et al. (117) defined well-being as a positive and sustainable state that enabled an individual, group, or nation to thrive and flourish. Participation in sports has been acknowledged as a viable means to promote well-being in youth (59,63,240); however, the International Olympic Committee stated that while youth should engage in sports, the process should be both pleasurable and fulfilling to sustain participation and success at all levels (21,177). Collectively, these philosophies should apply to all forms of physical activity for youth, inclusive of well-rounded strength and conditioning programs (69,196). Irrespective of whether a child is involved with competitive sports or recreational physical activity, health and well-being should at all times be a key priority of any long-term athletic training program.

Psychosocial Factors in Health and Well-Being. Youth should be exposed to positive experiences through sport and physical activity to maximize well-being. The primary reason that children initially engage in sport and physical activity is for fun, enjoyment, and to experience different activities (2). Similarly, a lack of fun and enjoyment is commonly the main cause of dropout from sport (32,51). To promote well-being in youth, practitioners should seek to develop (a) a growth mindset, (b) self-determined motivation, (c) perceived competence, (d) confidence, and (e) resilience (196). Specifically, a *growth mindset* will foster the belief that effort, purposeful practice, and guidance from qualified professionals will lead to development and success; while *self-determined motivation* reflects a state of mind that leads to a child participating in sport or physical activity for its interest, enjoyment, inherent satisfaction, and sense of challenge (221). *Perceived competence* is an important attribute to develop in youth, as it is strongly associated with participation in physical activity (140,214), especially during adolescence when the use of social comparison among youth and the role of peer support becomes more influential (30,222,223). *Confidence* is strongly related to reduced anxiety, positive emotions, and successful performance (260), whereas *resilience* is defined as the ability of an individual to retain stability or recover quickly under significant adverse conditions (137). To enhance well-being, qualified professionals should integrate a combination of strategies, including the use of mental skill training, process-oriented goals, and clear and positive feedback, while maintaining a fun agenda to all sessions. Similarly, qualified professionals should foster a training environment in which developmentally appropriate activities are prescribed, encouragement is reinforced, and whereby task failure is viewed as a positive aspect of the learning process.

Physical Factors in Health and Well-Being. Youth should engage in developmentally appropriate, well-rounded strength and conditioning programs from an early age that prioritize a long-term view to the development of athleticism. Therefore, chronic and sustainable adaptations should be the ultimate goal of youth training provision as opposed to acute gains in performance. Welfare is closely associated with the basic human rights of the child and will aid in the promotion of well-being (197). Training should at all times respect these rights and be commensurate with the technical competency, training history, and stage of growth and development of the child (178). Under no circumstance should physical exertion be forced that could be deemed abusive practice within a youth training program (129). Examples may include exercise programs that could be injurious activities that are not in any way beneficial, or prescription that could be viewed as a form of punishment (129). Forced physical exertion, prescribed as a form of physical punishment, can have severe physical consequences such as that which led to a 12-year-old boy being hospitalized with exertional rhabdomyolysis (41), a situation that is unethical and entirely unacceptable. Training prescription should be balanced with adequate rest to enable recovery and growth processes to occur and to avoid the risks of accumulated fatigue and associated risks of overtraining (57,162).

6. Youth Should Participate in Physical Conditioning That Helps Reduce the Risk of Injury to Ensure Their Ongoing Participation in Long-Term Athletic Development Programs

Although it is impossible to completely eliminate sport- and physical activity-related injuries, developmentally appropriate training can reduce the relative risks of injury in youth (21,74,109,141,190,217,236,245,256). More specifically, when youth participate in well-rounded strength and conditioning programs, inclusive of resistance training, motor skill and balance training, speed and agility training, and appropriate rest, the likelihood of experiencing an injury can be reduced by as much as 50% (172,256). The cause of the reduction in injury incidence, or injury risk factors, is likely due to improved movement biomechanics, increased muscle strength, and enhanced functional abilities (74,110,158,184). From a long-term athletic development perspective, it is imperative that youth, and those that are responsible for their developmental programming, realize the importance of following strength and conditioning programs that suitably prepare them for the demands of sport and physical activity. For example, early engagement in neuromuscular training is likely to result in a reduced risk of anterior cruciate ligament injury later in life in female athletes (190). The authors speculated that this finding was likely attributable to a window of opportunity for developing sound motor skills and concomitant strength levels before the onset of puberty, which is known to be a developmental stage in which youth experience significant alterations in movement biomechanics (81,113), force attenuation capabilities (207), and lower-limb strength ratios (208). It should also be recognized that sports participation alone does not provide a sufficient stimulus to develop high levels of athleticism in youth, as many sporting practices fail to provide adequate exposure to recommended daily physical activity guidelines (100,136), nor does it allow for individual needs to be addressed such as muscle imbalances or reduced ranges of motion (144).

"Underuse" as a Risk Factor for Injury. Although an abundance of existing data support the inclusion of preparatory conditioning for young athletes (21,64,123,190,246,256), the long-term development of athleticism must also be viewed as a valuable injury prevention tool for nonathletic youth. Physical inactivity is a major risk factor for activity-related injuries in children (25,243), and global statistics indicate that levels of inactivity in modern day youth remain worryingly high (191,252,254). Intuitively, much like young athletes who are often ill prepared for the high volumes of sport-specific practice and competitions, inactive youth are also unlikely to be suitably prepared for the demands of competitive/recreational sports or even general physical activity. For example, overweight and obese youth are twice as likely to suffer an injury during sports or recreational physical activity in comparison with their normal weight peers (165). Thus, "underuse" is likely the most dangerous risk factor for a number of youth, which

highlights the critical importance of appropriately designed long-term athletic development models.

Influence of Growth and Maturation on Injury Risk. Current data indicate that the risk of injury, in particular to the lower limb, peaks around the time of the adolescent growth spurt (33,58,113,185,258). During this period of rapid development, there are disproportionate growth rates between structural tissues, with bone growing earlier and at a faster rate than both muscle and tendon, which lag behind (130). The growth differential between these tissues can lead to discomfort and reduced flexibility around joints (130); however, it is the marked increase in the growth rate during this stage of development, which leads to increases in body mass and height of center of mass in the absence of corresponding adaptations in strength and power, which can lead to excessive loading of the musculoskeletal system during dynamic and reactive actions (111,130,185,258). For example, the rapid increases in both stature and body mass in female adolescents places them at increased risk of knee injury because of the increased stature developing without concomitant increases in hip and knee strength (185). The development of muscular imbalances around the pubertal growth spurt is also a viable risk factor, with longitudinal data in adolescent females showing that hamstring-to-quadriceps strength ratios decrease from prepubertal to pubertal stages (208). This muscle imbalance is of particular concern as when fatigued, both young and adult females use a less favorable activation strategy (56,128,167,202), reducing their ability to appropriately dissipate aberrant knee loads indicative of an anterior cruciate ligament injury mechanism (112,132). Although mechanistic data are required for young males, recently it has been suggested that the adolescent growth spurt is a developmental timeframe in which the risk of traumatic injury in pubertal males is intensified (228,258). Finally, bone mineralization typically lags behind linear bone growth during the pubertal spurt, thus leading to increased bone porosity and exposing the bone to a heightened risk of fracture (8). Consequently, irrespective of participation in competitive sports or noncompetitive recreational physical activity, all youth should participate in long-term training programs to promote the level of athleticism required to withstand the physical demands associated with their chosen activity and to offset growth- and maturity-associated risk factors.

7. Long-Term Athletic Development Programs Should Provide All Youth With a Range of Training Modes to Enhance Both Health- and Skill-Related Components of Fitness

Trainability of Youth. Trainability refers to the responsiveness of youth to a given training stimulus at various stages of development. As the field of pediatric exercise science continues to evolve, practitioners will gain a greater understanding of how responsive youth are to different modes of training. Our understanding of trainability typically emanates from largely discrete cross-sectional interventions, and these combined data indicate that both children and adolescents can make significant and worthwhile changes in motor skills (15,67,98), muscle strength and power (16,68,141), running speed (121,219), agility (122,171), and endurance performance (5,161,168). Recent data indicate that continual exposure to various training methods can benefit both children and adolescents (125,126,224). Of the longer-term interventions, 2 years of strength training have produced significant improvements in relative lower-body strength (125), faster change of direction speed (126), and 30-m sprint speed (224). Despite showing many benefits of strength training on measures of physical performance in youth, these studies did not account for the influence of maturation or sex on the rate and magnitude of change. Thus, the interaction of growth, maturation, and training during childhood and adolescence remains unclear and warrants further research.

Although strong evidence indicates that worthwhile gains in physical performance are achieved with strength and motor skill developmental models, limited evidence is available relative to the mode of exercise that should be prioritized at specific stages of development. Previous models of long-term athletic development have promoted the theory of "windows of opportunity" that provide youth with specific periods in which to train specific components of fitness (10), and failure to train specifically during these windows will limit performance capacity later in life (10). Although this theory attempted to bridge our understanding of growth, maturation, and training, this concept has since been challenged largely because of a lack of supporting longitudinal empirical data (82). Combined with the existing pediatric training literature, it becomes clear that both children and adolescents can make worthwhile improvements in all components of fitness irrespective of their stage of development (69,70,142,143), and consequently long-term training programs should seek to develop athleticism throughout the developmental period of childhood and adolescence.

Although both children and adolescents can make significant improvements in various physical fitness qualities (e.g., strength, motor skills, speed, and power), the most efficacious training modes used to acquire these adaptations may complement the physiological adaptations occurring as a result of growth and maturation, a process recently termed "synergistic adaptation" (69,147). Specifically, a meta-analysis examining the effects of different training methods on sprint speed development in male youth showed that boys who had not reached peak height velocity made the greatest improvements in sprinting after plyometric training, whereas boys who had reached peak height velocity responded more favorably to combined strength and plyometric training (219). Similar findings were recently reported in a 6-week training intervention that showed that both boys who had reached peak height velocity and those who had not were able to make significant improvements in jumping and sprinting after various 6-week resistance training programs (147). Plyometric training will promote similar neural adaptations that occur naturally as a result of growth and maturation before puberty, whereas combined strength and plyometric training will likely stimulate both neural and structural adaptations commonly seen after the pubertal growth spurt. Longitudinal research is now required to substantiate these claims of synergistic adaptation and to determine optimal training prescription for youth of different stages of development.

8. Practitioners Should Use Relevant Monitoring and Assessment Tools as Part of a Long-Term Athletic Development Strategy

For the welfare and well-being of youth, long-term training prescription should be complimented with appropriate monitoring and assessment tools. In the absence of careful monitoring, youth may be at an increased risk of excessively demanding training loads, insufficient opportunities for rest and regeneration, or contraindicating training methods (144). It is suggested that the training of youth should be monitored by qualified professionals to reduce the risks of excessive training (4,57,177) and accumulated fatigue (106), which in severe cases can lead to nonfunctional overreaching or overtraining (127,144,162,210). Those personnel responsible for the athletic development of youth should adopt a coordinated approach to the monitoring process. Wherever possible, qualified professionals should also attempt to educate children and their parents and raise awareness of the risks and symptoms of nonfunctional overreaching and related injuries or illnesses. The child and parents should also understand the roles of basic self-reporting monitoring strategies (sleep patterns, nutritional behavior, and physical activity exposure outside the training environment) and the potential impact of appropriate remedial strategies.

Qualified professionals will typically use monitoring and assessment tools to determine training for effectiveness, to aid in program design, determining mechanisms of adaptation, to instill motivation within the child or adolescent, or to obtain further knowledge and understanding about the physiological demands of a sport or physical activity. However, various testing and assessment strategies are also used for the purposes of talent identification (204). Although a goal of identifying future potential talent is perhaps appealing, the process of identifying and subjectively selecting talent from a very early age typically favors early maturing, while excluding later maturing youth (31,43,91,164,225). Additionally, a comprehensive talent identification process is often time-consuming and expensive, and, crucially, the success rate of identified children transferring through to elite-level adult sport is questionable (255).

Although a wealth of monitoring and assessment tools are available for practitioners, the number and sophistication of tools included within any long-term athletic development program should be dependent on the efficacy and relevance of the tests, their associated measurement error, the availability of time, equipment, and facilities, and the degree of the practitioner's expertise. Importantly, practitioners should select tests that are accurate, reliable, and valid and provide meaningful data. Similarly, at all times, it is essential that practitioners adhere to the ethics of pediatric testing, clearly explain all protocols to both children and parents, and collect both parental consent and participant assent before any testing (244,266).

Monitoring Growth and Maturation. Because of the influence of growth and maturation on measures of physical performance (22,261), relative risk of injury (81,113,258), and the propensity for early maturing youth to be selected in sports teams as a result of the relative age effect (89,93,226), it seems plausible that practitioners should attempt to monitor physical growth throughout childhood and adolescence. Recent reviews have provided summaries of existing methods for the identification, or at least estimation, of biological maturation (145,156). It is acknowledged that the invasive methods have their own strengths and weaknesses, whereas noninvasive methods of estimating maturity require further validation especially within different ethnicities (154,156). Despite the need for further research, it is recommended that where practitioners are working with youth for a prolonged period, quarterly assessments of stature, limb length, and body mass are taken to allow the analysis of growth curves. This information can be collected and provide practitioners with relevant information to help explain fluctuations in performance and aid in the identification of youth who are experiencing rapid growth, which may potentially place them "at risk" of growth-related injury (145).

Monitoring Physical Performance. There are a myriad of existing test protocols for assessing physical capacities, such as muscle strength and power (72,73,86,141,173), running speed (170,218), aerobic capacity (6,11,263), or motor skill competency (46,47,60), and practitioners should adopt those that are most viable for their particular environment. For example, it may be feasible for practitioners within elite youth sports teams to assess kinetics and kinematics using force plate diagnostics and motion capture systems (184), whereas a primary school teacher may only be able to test a child's performance on a standing broad jump (7) and collect some data on how subjectively difficult training sessions were by using a child-modified version of the rating scale of perceived exertion (99). Both scenarios are likely to provide valuable information related to athletic development and subsequent training prescription. Qualified professionals should appreciate that when assessing physical capacities in youth, it is important to value both the process of performance (i.e., how technically proficient an individual performs a jumping movement) and the product of performance (i.e., how far do they jump).

Monitoring Psychosocial Well-Being. Although practitioners may instinctively focus on assessing and monitoring measures of physical performance, for the holistic development of youth, it is imperative that consideration also be given to psychosocial well-being (197). Various tools for monitoring well-being have been reported in the literature; a modified version of the Profile of Mood States questionnaire has previously been shown to be a valid tool for assessing mood in adolescents (249); the recovery-stress questionnaire has been used to identify nonfunctional overreaching in youth (29); the acute recovery and stress scale has been shown to be a sensitive and valid tool to monitor recovery stress imbalances (131), whereas researchers recently showed how a simple well-being questionnaire (166) was able to detect perceived well-being in a group of adolescents (199). The well-being questionnaire consists of 5 key items (fatigue, sleep quality, general muscle soreness, stress levels, and mood) in which youth provide a score on a rating scale of 1 (least positive response) to 5 (most positive response) in 0.5 increments (166,199). Although psychosocial well-being is multifactorial, it is suggested that practitioners use some form of monitoring system to help identify youth who are potentially "at risk" of low well-being and to ensure that children and adolescents remain motivated to participate in sports or physical activity. Where practitioners are unable to directly monitor or record data, they should have an awareness of the warning signs of reduced well-being. For example, Matos et al. (162) identified the following as the most prevalent symptoms of overtraining in youth: loss of appetite, increased frequency of injury, frequent tiredness, inability to cope with training loads, frequent respiratory infections, heavy and stiff muscles, and disrupted sleep patterns.

9. Practitioners Working With Youth Should Systematically Progress and Individualize Training Programs for Successful Long-Term Athletic Development

When working within a long-term athletic development pathway, it is imperative wherever possible, for qualified professionals to adopt a progressive, individualized, and integrated approach to the programming of strength and conditioning activities. Regardless of whether a practitioner is working with an overweight prepubertal boy who is re-engaging with physical activity, or a talented adolescent girl with 8 years of high-quality training experience, there should be a clear goal commensurate with the needs of the individual. Although existing athletic development models provide generic guidelines for qualified professionals to consider for the long-term development of athleticism (142,143), the process of designing, implementing, and refining youth training programs should be dictated by the needs of the individual, their technical competency, and the needs of the relevant sports or activities. Also, program design and delivery should accommodate for other influential factors such as the time and facilities available for training, the pressures of academic work, and the need for socializing with family and friends.

Challenges Associated With Programming for Youth. Periodization represents the theoretical framework for developing a training program (203) and involves planning sequential blocks of training to maximize the overall training response. However, in the event of insufficient time allowance for rest and recovery, fatigue will accumulate and potentially lead to nonfunctional overreaching or in extreme cases, overtraining, or burnout (169). Fatigue management and the prevention of overtraining are recognized as key determinants of successful programming (206), and the long-term development of athleticism in youth is predicated by balancing exposure to training with sufficient time for rest, recovery, and growth. Much like in adults, failure to accommodate for periods of rest will undoubtedly make children more susceptible to the negative consequences of overtraining or overuse injury (36,162). Planning for rest and recovery to enable natural growth processes to occur is a key moderator that differentiates youth programming from that of adults.

The challenge of balancing training stimuli with recovery time becomes even more difficult where youth are engaged in multiple sports or activities in successive seasons (e.g., a fall, a winter, and a summer sport), or play for multiple teams within a single season (e.g., youth who play soccer at club, regional, and national levels). Dismissing the need for adequate rest and recovery blocks will likely predispose youth to decrements in physical and psychological function (36). Therefore, when designing programs, practitioners should prescribe rest and recovery periods as mandatory blocks of the overall training plan, irrespective of pressures from sports coaches or parents. To optimize physical development and minimize accumulated fatigue, practitioners should also consider the scheduling of training vs. competitions. For young children entering a long-term athletic development pathway, researchers suggest that a large proportion of time should be devoted to general preparatory training with a focus on development of fundamental movement skills and foundational strength; then, as children becomes older, a greater amount of time could then be devoted to their chosen sport or physical activity (103). Practitioners should also be cognizant of the risks associated with prolonged competitions and the amount of rest between, and leading up to, competition (187). Intensive competitions lasting 6 hours or more with insufficient rest are a risk factor for injury (27); however, researchers also advocate that in the event of multiple competitions taking place on the same day, youth should be allowed adequate and predetermined rest intervals between repeated bouts of activity (20). In the lead up to a sporting event, it has also been suggested that youth should be afforded at least 48 hours of rest before a competition and be encouraged to sleep for longer than 7 hours per night (150) because of the negative effects of insufficient sleep on health, learning, and physical performance (21,34,90).

Influence of Growth and Maturation on Programming. Because development in youth occurs in a nonlinear fashion, practitioners need to be flexible and responsive to interindividual variations in the timing, tempo, and magnitude of physical maturation, differences in psychosocial maturation, and differences in rates and styles of learning. For example, during the growth spurt, a child may experience temporary disruption in motor control and whole-body coordination, commonly termed “adolescent awkwardness” (205,209). In such an instance, practitioners may need to adjust the training program by prescribing opportunities to modify existing motor patterns with reduced loadings (145). This scenario highlights the importance of qualified professionals working with youth to not only possess a sound understanding of the training process and an ability to observe and correct technique but also an understanding of key pediatric exercise science principles.

10. Qualified Professionals and Sound Pedagogical Approaches Are Fundamental to the Success of Long-Term Athletic Development Programs

Although a clear understanding of pediatric exercise science and training principles are fundamental to the long-term development of athleticism in youth, a strong grounding in pedagogy and coaching skills is also a necessity for the practitioner to effectively communicate and interact with youth of all ages and abilities (71,142,144). Practitioners should be able to call on a wide range of teaching strategies to ensure that all youth are exposed to mentally engaging and physically challenging training programs that foster a motivational climate and inspire holistic development from both a physical and psychosocial perspective. The ability to promote a motivational learning climate, in which all youth are able to participate in a variety of developmentally appropriate activities, engage in personal reflection, experience success, and enhance competence (102), is an essential tool for practitioners to maximize the development of athleticism. From a holistic perspective, practitioners should seek to promote intrinsic motivation in youth as this will encourage a child or adolescent to be interested in participating, improving, and developing skills, while also reducing the risk of youth being solely driven by external rewards, such as trophies or scholarships. Cultivating an environment that promotes intrinsic motivation and enjoyment while minimizing the negative effects of stress will result in the best outcome for youth who need to learn and understand that successful performance emanates from effort, hard work, and desire (26,124,232–234).

Within the motivational climate, practitioners should demonstrate, explain, cue, and modify exercises in a developmentally appropriate manner. Although in the initial stages of developing athleticism, a practitioner may need to provide guidance and feedback to teach basic motor patterns, in most instances a combination of visual demonstration with concise external cues should be prioritized to maximize the learning and feedback processes (17,94). Recent evidence shows the benefits of using external as opposed to internal cues in the performance of rotational jumping techniques in young gymnasts (1), with researchers suggesting that attentional focus is improved when using externally oriented cueing. Effective management of children and adolescents, either within a competitive sporting or recreational physical activity environment, will also require clear and well-prepared session structures (144), effective use of instruction (97), behavior management strategies (213), use of empowerment, varied use of projection and tone of voice, and a teaching style that inspires youth to continually engage in a lifetime of physical activity.

Summary

It is clear that the field of long-term athletic development has progressed over recent years; however, owing to the current lack of longitudinal and well-controlled empirical studies, further research is required. Specifically, a better understanding of the training process in youth, the manner in which training interacts with growth and maturation, and how long-term approaches to athletic development influence physical performance, health and well-being, and injury risk are key areas that require further study. This new research is also required to validate existing practices among qualified professionals and to ensure that youth are provided with evidence-based practice at all times. All youth should be afforded training programs commensurate with their individual needs, which foster a fun and motivational training environment. However, above all else, it is imperative that qualified professionals adhere to the words of President Franklin D. Roosevelt and help to build our youth for a lifelong future of healthy and enjoyable engagement in sports and physical activity.

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