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THE NATIONAL STRENGTH AND CONDITIONING ASSOCIATION POSITION STATEMENT ON LONG-TERM ATHLETIC DEVELOPMENT

--Manuscript Draft--

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Abstract:	There has recently been a growing interest in long-term athletic development for youth. Due to 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 behaviours 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 that are physically underprepared and at risk of overuse injury due to 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-centred manner. Due to the 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. Figure 1 provides a list of the 10 pillars of successful long-term athletic development, which summarize the key recommendations detailed within the consensus statement. With these pillars in place, it is believed that the NSCA can (i) help foster a more unified and holistic approach to youth physical development, (ii) promote the benefits of a lifetime of healthy physical activity, and (iii) prevent and/or minimize injuries from sports participation for all boys and girls.
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THE NATIONAL STRENGTH AND CONDITIONING ASSOCIATION POSITION STATEMENT ON LONG-TERM ATHLETIC DEVELOPMENT

ABSTRACT

There has recently been a growing interest in long-term athletic development for youth. Due to 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 behaviours 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 that are physically underprepared and at risk of overuse injury due to 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-centred manner. Due to the 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. *Figure 1* provides a list of the 10 pillars of successful long-term athletic development, which summarize the key

recommendations detailed within the consensus statement. With these pillars in place, it is believed that the NSCA can (i) help foster a more unified and holistic approach to youth physical development, (ii) promote the benefits of a lifetime of healthy physical activity, and (iii) 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*

****Figure 1 near here****

OPERATIONAL TERMS

Throughout this manuscript, the following operational terms are defined as:

- *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.
- 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 two 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 (i) an appropriate understanding of pediatric exercise science, exercise prescription, technique evaluation, and testing methods, (ii) relevant coaching experience and a strong pedagogical background, and (iii) 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. While 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).

1. Long-term athletic development pathways should accommodate for the highly individualized and non-linear nature of the growth and development of youth.

It is commonly stated that "children are not miniature adults" and due to their immature physiological and psychosocial state, they should be prescribed appropriate training programs 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 in comparison to 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 non-linear 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 towards a mature state, and varies in timing and tempo, and between different systems within the body (22). Significant inter-individual 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 amongst 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 that 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 preventative treatments for unfavourable 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 are encouraged to enhance athleticism from an early age by engaging with multi-faceted training inclusive of a range of different training modes (142). Previous misconceptions regarding the impact of physical training on growth and development trajectories are not supported with literature, especially as data are often correlational and cross-sectional in nature (22, 156). While 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 in order to i) prescribe training programs that are commensurate with the needs and abilities of the individual, ii) distinguish between training-induced and growth-related adaptations in performance (either positive or negative), and iii) 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 wellbeing.

The development of physical fitness in youth is a complex process, which involves the 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 behaviours (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 amongst 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 two primary corollaries are evident within the pediatric literature. *Firstly*, 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 unfavourable 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 behavioural patterns reflective of EDD should be prescribed exercise interventions geared towards the development of fundamental movement skills, foundational strength and general athleticism (76). The prevalence of substandard athleticism in modern-day youth will likely increase the prevalence of overweight or obese youth (114, 115), but also increase the relative risk of injury for inactive youth who eventually engage with physical activity or sports (25). *Secondly*, a growing concern for practitioners is the number of youth reporting with sport-related injuries as a consequence of over exposure 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 non-functional overreaching, overtraining, burnout and eventual drop out 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 non-functional overreaching or overtraining.

Due to 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. While 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). While 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 versus 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 individualised 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 with 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). While correct execution of fundamental motor skills requires coordinated sequencing of multi-muscle, multi-joint, multi-planar 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. While 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 as 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 wellbeing, 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 with exploratory and deliberate play from early childhood (from birth up 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 with 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 due to 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 non-guarantee 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 with sports often due to 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 three 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 hour 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). However, while 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 centimetres, 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 towards the end of adolescence, leading to greater volumes of training towards early adulthood. Similarly, adopting a sampling approach and investing in multiple sports as opposed to specializing in a single sport produced improved performances in gross motor coordination and standing broad jump tests in 10-12 year old boys (84). In addition, the analysis of retrospective data across a multitude of sports indicates that individuals who participated in three sports or more between 11-15 years of age were more likely to play national compared with club standard sport between 16-18 years (28).

Effects of early specialization on injury risk

The risks of overuse injury appear to increase as a result of early specialization due to the repetitive sub-maximal loading on the musculoskeletal system in the absence of sufficient recovery time for subsequent adaptation (57, 239). For example, data showed that from a sample of female youth athletes, 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), while 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 eight months per year in a single sport (120, 200), while 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 over stress 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). With regards to 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 wellbeing of the child should always be the central tenet of long-term athletic development programs.

Health can be defined as "a condition of wellbeing free of disease or infirmity and a basic and universal human right" (227). Huppert et al. (117) defined wellbeing 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 wellbeing in youth (59, 63, 240); however the International Olympic Committee stated that while youth should engage with sports, the process should be both pleasurable and fulfilling in order 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 wellbeing should at all times be a key priority of any long-term athletic training program.

Psychosocial factors in health and wellbeing

Youth should be exposed to positive experiences through sport and physical activity to maximize wellbeing. The primary reason that children initially engage with 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 wellbeing in youth, practitioners should seek to develop (i) a growth mind-set, (ii) self-determined motivation, (iii) perceived competence, (iv) confidence and (v) resilience (196). Specifically, a *growth mind-set* 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 where 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), while *resilience* is defined as the ability of an individual to retain stability or recover quickly under significant adverse conditions (137). To enhance wellbeing, qualified professionals should integrate a combination of strategies, including the use of mental skill training, process-oriented

goals, 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 wellbeing

Youth should engage with 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 wellbeing (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 which 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 on-going participation in long-term athletic development programs.

While 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 for 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 prior to the onset of puberty which is known to be a developmental stage where 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

While an abundance of data now exist that supports 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 non-athletic 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 to 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 growth rate during this stage of development which leads to increases in body mass and height of centre 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 due to 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 pre-pubertal to pubertal stages (208). This muscle imbalance is of particular concern as when fatigued, both young and adult females utilize a less favourable 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 time frame 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 non-competitive 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 indicates that continual exposure to various training methods can benefit both children and adolescents (125, 126, 224). Of the longer-term interventions, two years of strength training have produced significant improvements in relative lower body strength (125); faster change of direction speed (126); and 30 meter sprint speed (224). Despite showing the 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 rate and magnitude of change. Thus, the interaction of growth, maturation and training during childhood and adolescence remains unclear and warrants further research.

Whereas 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 time periods in which to train specific components of fitness (10), and failure to train specifically during these windows limiting performance capacity later in life (10). While this theory attempted to bridge our understanding of growth, maturation and training, this concept has since been challenged largely owing to a lack of supporting longitudinal empirical data (82). Combined with 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.

While 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 were pre-peak height velocity made the greatest improvements in sprinting following plyometric training, while boys who were post-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 boys who were either pre- or post-peak height velocity were all able to make significant improvements in jumping and sprinting following various 6-week resistance training programs (147). Plyometric training will promote similar neural adaptations that are occurring naturally as a result of growth and maturation

prior to puberty, while 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 wellbeing 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 non-functional overreaching or overtraining (127, 144, 162, 210). Those personnel responsible for the athletic development of youth should adopt a co-ordinated approach to the monitoring process. Wherever possible, qualified professionals should also attempt to educate the child and their parents and raise awareness of the risks and symptoms of non-functional overreaching and related injuries or illnesses. The child and parents should also understand the roles of basic self-reporting monitoring strategies (sleep patterns, nutritional behaviour, physical activity exposure outside of 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 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 favours early maturing, while excluding later maturing youth (31, 43, 91, 164, 225). Additionally, a comprehensive talent identification process is often time-consuming, expensive and, crucially, the success rates 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 upon 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 prior to any testing (244, 266).

Monitoring growth and maturation

Due to 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, while non-invasive 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 of time, 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 (RPE) (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 wellbeing

While 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 wellbeing (197). Various wellbeing monitoring tools 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 non-functional 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), while researchers recently showed how a simple wellbeing questionnaire (166) was able to detect perceived wellbeing in a group of adolescents (199). The wellbeing questionnaire consists of five 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). While psychosocial wellbeing is multifactorial, it is suggested that practitioners utilize some form of monitoring system to help identify youth that

are potentially "at risk" of low wellbeing 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 wellbeing. For example Matos et al. (162) identified the most prevalent symptoms of overtraining in youth as: a 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 eight years of high quality training experience, there should be a clear goal commensurate with the needs of the individual. While 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 non-functional over-reaching 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 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 with 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 level). 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. In order to optimize physical development and minimize accumulated fatigue, practitioners should also consider the scheduling of training

versus 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 the child 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); while researchers also advocate that in the event of multiple competitions taking place on the same day, youth should be allowed adequate and pre-determined 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 prior to a competition and encouraged to sleep for longer than 7 hours per night (150) due to the negative effects of insufficient sleep on health, learning and physical performance (21, 34, 90).

Influence of growth and maturation on programming

Due to the fact that development in youth occurs in a non-linear fashion, practitioners need to be flexible and responsive to inter-individual 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

While 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 in order 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 in order 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. While 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. The 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), behaviour management strategies (213), the 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 wellbeing and injury risk are key areas that require further

study. This new research is also required to validate existing practices amongst 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 with sports and physical activity.

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TITLE:

THE NATIONAL STRENGTH AND CONDITIONING ASSOCIATION POSITION STATEMENT ON LONG-TERM ATHLETIC DEVELOPMENT

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Figure 1. The 10 pillars for successful long-term athletic development

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 physical 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.

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To whom it may concern,

This is a cover letter for the manuscript entitled:

- **THE NATIONAL STRENGTH AND CONDITIONING ASSOCIATION POSITION STATEMENT ON LONG-TERM ATHLETIC DEVELOPMENT**

As the first author and author for correspondence I would like to state that:

- **The manuscript has been read and approved by all the listed co-authors and meets the requirements of co-authorship as specified in the Authorship Guidelines for the Journal of Strength and Conditioning Research"**

- **This manuscript contains material that is original and not previously published in text or on the Internet, nor is it being considered elsewhere until a decision is made as to its acceptability by the Journal of Strength and Conditioning Research Editorial Review Board.**

- **I can confirm that all listed authors have contributed to the production of the manuscript, and no other academics, researchers, affiliations or funding has had any association with the project.**

- **I can confirm that there are no conflicts of interest to acknowledge**

I would like to thank you for considering publishing the manuscript and look forward to hearing from you in the near future.

Sincerely

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