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

349 ‘blunting’ of an individual’s motor skill portfolio (57, 144, 176, 186), a reduced
350 standard of performance later in life (28, 84, 96, 174, 268), an increased risk of
351 overtraining or dropout from sport or physical activity (4, 35, 151, 187), and the non-
352 guarantee of achieving elite level performance (28, 101, 174).
353
354 *Effects of early specialization on physical performance*
355 Irrespective of the potential risks associated with early sport specialization, both
356 children and adolescents are being encouraged to engage earlier with sports often due
357 to the lure of a higher standard of performance, for example securing national team
358 selection, college scholarships or professional contracts. The assumption that earlier
359 specialization will lead to enhanced sports performance has largely been driven by the
360 incorrect extrapolation of data examining the development of expert musicians and
361 the proposed “10,000 hour rule” (66). The rule denotes that an individual must
362 acquire 10,000 hours of deliberate practice to attain mastery in a given sport or
363 activity, which could also be viewed as dedicating specific practice to the same sport
364 or activity for three hours a day for 10 years. However, in a recent editorial it was
365 suggested that their seminal work on expert performers had been misinterpreted and
366 that expert performance had been achieved by some with just 5,000 hours of practice
367 (65), which is more reflective of the training volumes reported for actual sports
368 performers (174). Consequently, practitioners should not subscribe to the hypothetical
369 10,000 hour rule, but instead value the *quality* of practice rather than a specific
370 *quantity* of practice.
371
372 The early specialization approach is particularly common when young children
373 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

523 does it allow for individual needs to be addressed such as muscle imbalances or
524 reduced ranges of motion (144).
525
526 *'Underuse' as a risk factor for injury*
527 While an abundance of data now exist that supports the inclusion of preparatory
528 conditioning for young athletes (21, 64, 123, 190, 246, 256), the long-term
529 development of athleticism must also be viewed as a valuable injury prevention tool
530 for non-athletic youth. Physical inactivity is a major risk factor for activity-related
531 injuries in children (25, 243) and global statistics indicate that levels of inactivity in
532 modern day youth remain worryingly high (191, 252, 254). Intuitively, much like
533 young athletes who are often ill prepared for the high volumes of sport-specific
534 practice and competitions, inactive youth are also unlikely to be suitably prepared for
535 the demands of competitive/recreational sports or even general physical activity. For
536 example, overweight and obese youth are twice as likely to suffer an injury during
537 sports or recreational physical activity in comparison to their normal weight peers
538 (165). Thus, 'underuse' is likely the most dangerous risk factor for a number of youth,
539 which highlights the critical importance of appropriately designed long-term athletic
540 development models.
541
542 *Influence of growth and maturation on injury risk*
543 Current data indicate that the risk of injury, in particular to the lower limb, peaks
544 around the time of the adolescent growth spurt (33, 58, 113, 185, 258). During this
545 period of rapid development, there are disproportionate growth rates between
546 structural tissues, with bone growing earlier and at a faster rate than both muscle and
547 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

598 the theory of ‘windows of opportunity’ that provide youth with specific time periods
599 in which to train specific components of fitness (10), and failure to train specifically
600 during these windows limiting performance capacity later in life (10). While this
601 theory attempted to bridge our understanding of growth, maturation and training, this
602 concept has since been challenged largely owing to a lack of supporting longitudinal
603 empirical data (82). Combined with existing pediatric training literature, it becomes
604 clear that both children and adolescents can make worthwhile improvements in all
605 components of fitness irrespective of their stage of development (69, 70, 142, 143),
606 and consequently long-term training programs should seek to develop athleticism
607 throughout the developmental period of childhood and adolescence.
608
609 While both children and adolescents can make significant improvements in various
610 physical fitness qualities (e.g. strength, motor skills, speed and power), the most
611 efficacious training modes used to acquire these adaptations may complement the
612 physiological adaptations occurring as a result of growth and maturation, a process
613 recently termed ‘synergistic adaptation’ (69, 147). Specifically, a meta-analysis
614 examining the effects of different training methods on sprint speed development in
615 male youth showed that boys who were pre-peak height velocity made the greatest
616 improvements in sprinting following plyometric training, while boys who were post-
617 peak height velocity responded more favorably to combined strength and plyometric
618 training (219). Similar findings were recently reported in a 6-week training
619 intervention that showed boys who were either pre- or post-peak height velocity were
620 all able to make significant improvements in jumping and sprinting following various
621 6-week resistance training programs (147). Plyometric training will promote similar
622 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

721 are potentially “at risk” of low wellbeing and to ensure that children and adolescents
722 remain motivated to participate in sports or physical activity. Where practitioners are
723 unable to directly monitor or record data, they should have an awareness of the
724 warning signs of reduced wellbeing. For example Matos et al. (162) identified the
725 most prevalent symptoms of overtraining in youth as: a loss of appetite, increased
726 frequency of injury, frequent tiredness, inability to cope with training loads, frequent
727 respiratory infections, heavy and stiff muscles and disrupted sleep patterns.
728
729 **9. Practitioners working with youth should systematically progress and**
730 **individualize training programs for successful long-term athletic development**
731 When working within a long-term athletic development pathway, it is imperative
732 wherever possible, for qualified professionals to adopt a progressive, individualized
733 and integrated approach to the programming of strength and conditioning activities.
734 Regardless of whether a practitioner is working with an overweight prepubertal boy
735 who is re-engaging with physical activity, or a talented adolescent girl with eight
736 years of high quality training experience, there should be a clear goal commensurate
737 with the needs of the individual. While existing athletic development models provide
738 generic guidelines for qualified professionals to consider for the long-term
739 development of athleticism (142, 143), the process of designing, implementing and
740 refining youth training programs should be dictated by the needs of the individual,
741 their technical competency, and the needs of the relevant sports or activities. Also,
742 program design and delivery should accommodate for other influential factors such as
743 the time and facilities available for training, the pressures of academic work, and the
744 need for socializing with family and friends.
745

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

820 in the best outcome for youth who need to learn and understand that successful
821 performance emanates from effort, hard work and desire (26, 124, 232-234).
822
823 Within the motivational climate, practitioners should demonstrate, explain, cue and
824 modify exercises in a developmentally appropriate manner. While in the initial stages
825 of developing athleticism a practitioner may need to provide guidance and feedback to
826 teach basic motor patterns, in most instances a combination of visual demonstration
827 with concise external cues should be prioritized to maximize the learning and
828 feedback processes (17, 94). Recent evidence shows the benefits of using external as
829 opposed to internal cues in the performance of rotational jumping techniques in young
830 gymnasts (1), with researchers suggesting that attentional focus is improved when
831 using externally oriented cueing. The effective management of children and
832 adolescents, either within a competitive sporting or recreational physical activity
833 environment, will also require clear and well prepared session structures (144),
834 effective use of instruction (97), behaviour management strategies (213), the use of
835 empowerment, varied use of projection and tone of voice, and a teaching style that
836 inspires youth to continually engage in a lifetime of physical activity.
837
838 **Summary**
839 It is clear that the field of long-term athletic development has progressed over recent
840 years; however, owing to the current lack of longitudinal and well-controlled
841 empirical studies, further research is required. Specifically, a better understanding of
842 the training process in youth, the manner in which training interacts with growth and
843 maturation, and how long-term approaches to athletic development influence physical
844 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.

References

1. Abdollahipour R, Wulf G, Psotta R, and Palomo Nieto M. Performance of gymnastics skill benefits from an external focus of attention. *J Sports Sci* 33: 1807-1813, 2015.

2. Allender S, Cowburn G, and Foster C. Understanding participation in sport and physical activity among children and adults: a review of qualitative studies. *Health Educ Res* 21: 826-835, 2006.

3. Alvarez-San Emeterio C, Antunano NP, Lopez-Sobaler AM, and Gonzalez-Badillo JJ. Effect of strength training and the practice of Alpine skiing on bone mass density, growth, body composition, and the strength and power of the legs of adolescent skiers. *J Strength Cond Res* 25: 2879-2890, 2011.

4. American Academy of Pediatrics Council on Sports M. Intensive training and sports specialization in young athletes. *Pediatrics* 106: 154-157, 2000.

5. Armstrong N and Barker AR. Endurance training and elite young athletes. *Med Sports Sci* 56: 59-83, 2011.

6. Armstrong N and Welsman JR. Assessment: aerobic fitness, in: *Paediatric Exercise Science and Medicine, 2nd Ed*. N Armstrong, W Van Mechelen, eds. Oxford: Oxford University Press, 2008, pp 97-108.

7. Artero EG, Espana-Romero V, Castro-Pinero J, Ruiz J, Jimenez-Pavon D, Aparicio V, Gatto-Cardia M, Baena P, Vicente-Rodriguez G, Castillo MJ, and Ortega FB. Criterion-related validity of field-based muscular fitness tests in youth. *J Sports Med Phys Fitness* 52: 263-272, 2012.

8. Bailey DA, Wedge JH, McCulloch RG, Martin AD, and Bernhardson SC. Epidemiology of fractures of the distal end of the radius in children as associated with growth. *J Bone Joint Surg Am* 71: 1225-1231, 1989.

9. Bailey R and Morley D. Towards a model of talent development in physical education. *Sport Educ Soc* 11: 211-230, 2006.

10. Balyi I and Hamilton A. *Long-term athlete development: trainability in childhood and adolescence. Windows of Opportunity. Optimal trainability.* Victoria, British Columbia, Canada: National Coaching Institute & Advanced Training and Performance, 2004.

11. Barker AR, Williams CA, Jones AM, and Armstrong N. Establishing maximal oxygen uptake in young people during a ramp cycle test to exhaustion. *Br J Sports Med* 45: 498-503, 2011.

12. Bartlett R, Wheat J, and Robins M. Is movement variability important for sports biomechanists? *Sports Biomech* 6: 224-243, 2007.

13. Bass SL. The prepubertal years: a uniquely opportune stage of growth when the skeleton is most responsive to exercise? *Sports Med* 30: 73-78, 2000.

14. Baxter-Jones ADG, Eisenmann JC, and Sherar LB. Controlling for maturation in pediatric exercise science. *Pediatr Exerc Sci* 17: 18-30, 2005.

15. Behringer M, Vom Heede A, Matthews M, and Mester J. Effects of strength training on motor performance skills in children and adolescents: a meta-analysis. *Pediatr Exerc Sci* 23: 186-206, 2011.

16. Behringer M, Vom Heede A, Yue Z, and Mester J. Effects of resistance training in children and adolescents: a meta-analysis. *Pediatrics* 126: e1199-1210, 2010.

17. Benjaminse A, Gokeler A, Dowling AV, Faigenbaum A, Ford KR, Hewett TE, Onate JA, Otten B, and Myer GD. Optimization of the anterior cruciate ligament injury prevention paradigm: novel feedback techniques to enhance motor learning and reduce injury risk. *J Orthop Sports Phys Ther* 45: 170-182, 2015.

18. Benson AC, Torode ME, and Fiatarone Singh MA. The effect of high-intensity progressive resistance training on adiposity in children: a randomized controlled trial. *Int J Obes (Lond)* 32: 1016-1027, 2008.

19. Benson AC, Torode ME, and Fiatarone Singh MA. Effects of resistance training on metabolic fitness in children and adolescents: a systematic review. *Obes Rev* 9: 43-66, 2008.

20. Bergeron MF, Laird MD, Marinik EL, Brenner JS, and Waller JL. Repeated-bout exercise in the heat in young athletes: physiological strain and perceptual responses. *J Appl Physiol (1985)* 106: 476-485, 2009.

21. Bergeron MF, Mountjoy M, Armstrong N, Chia M, Cote J, Emery CA, Faigenbaum A, Hall G, Jr., Kriemler S, Leglise M, Malina RM, Pensgaard AM, Sanchez A, Soligard T, Sundgot-Borgen J, van Mechelen W, Weissensteiner JR, and Engebretsen L. International Olympic Committee consensus statement on youth athletic development. *Br J Sports Med* 49: 843-851, 2015.

22. Beunen GP and Malina RM. Growth and biological maturation: relevance to athletic performance, in: *The Young Athlete*. H Hebestreit, O Bar-Or, eds. Oxford: Blackwell Publishing, 2008, pp 3-17.

23. Beunen GP, Rogol AD, and Malina RM. Indicators of biological maturation and secular changes in biological maturation. *Food Nutr Bull* 27: S244-256, 2006.

24. Biddle SJ and Asare M. Physical activity and mental health in children and adolescents: a review of reviews. *Br J Sports Med* 45: 886-895, 2011.

25. Bloemers F, Collard D, Paw MC, Van Mechelen W, Twisk J, and Verhagen E. Physical inactivity is a risk factor for physical activity-related injuries in children. *Br J Sports Med* 46: 669-674, 2012.

26. Breiger J, Cumming SP, Smith RE, and Smoll F. Winning, motivational climate, and young athletes' competitive experiences: some notable sex differences. *Int J Sports Sci Coach* 10: 395-411, 2015.

27. Brenner JS, American Academy of Pediatrics Council on Sports M, and Fitness. Overuse injuries, overtraining, and burnout in child and adolescent athletes. *Pediatrics* 119: 1242-1245, 2007.

28. Bridge MW and Toms MR. The specialising or sampling debate: a retrospective analysis of adolescent sports participation in the UK. *J Sports Sci* 31: 87-96, 2013.

29. Brink MS, Visscher C, Coutts AJ, and Lemmink KA. Changes in perceived stress and recovery in overreached young elite soccer players. *Scand J Med Sci Sports* 22: 285-292, 2012.

30. Buhrmester D and Furman W. The development of companionship and intimacy. *Child Dev* 58: 1101-1113, 1987.

31. Burgess DJ and Naughton GA. Talent development in adolescent team sports: a review. *Int J Sports Physiol Perform* 5: 103-116, 2010.

32. Butcher J, Lindner KJ, and John DP. Withdrawal from competitive youth sport: a retrospective ten-year study. *J Sport Behav* 25: 145-163, 2002.

33. Caine D, Maffulli N, and Caine C. Epidemiology of injury in child and adolescent sports: injury rates, risk factors, and prevention. *Clin Sports Med* 27: 19-50, vii, 2008.

34. Carskadon MA. Sleep and circadian rhythms in children and adolescents: relevance for athletic performance of young people. *Clin Sports Med* 24: 319-328, x, 2005.

35. Carter CW and Micheli LJ. Training the child athlete for prevention, health promotion, and performance: how much is enough, how much is too much? *Clin Sports Med* 30: 679-690, 2011.

36. Carter CW and Micheli LJ. Training the child athlete: physical fitness, health and injury. *Br J Sports Med* 45: 880-885, 2011.

37. Casey BJ, Giedd JN, and Thomas KM. Structural and functional brain development and its relation to cognitive development. *Biol Psychol* 54: 241-257, 2000.

38. Casey BJ, Tottenham N, Liston C, and Durston S. Imaging the developing brain: what have we learned about cognitive development? *Trends Cogn Sci* 9: 104-110, 2005.

39. Cattuzzo MT, Dos Santos Henrique R, Re AH, de Oliveira IS, Melo BM, de Sousa Moura M, de Araujo RC, and Stodden D. Motor competence and health related physical fitness in youth: A systematic review. *J Sci Med Sport*, 2014.

40. Ceschia A, Giacomini S, Santarossa S, Rugo M, Salvadego D, Da Ponte A, Driussi C, Mihaleje M, Poser S, and Lazzer S. Deleterious effects of obesity on physical fitness in pre-pubertal children. *Eur J Sport Sci*: 1-8, 2015.

41. Clarkson PM. Case report of exertional rhabdomyolysis in a 12-year-old boy. *Med Sci Sports Exerc* 38: 197-200, 2006.

971 42. Cliff DP, Okely AD, Morgan PJ, Jones RA, Steele JR, and Baur LA.
972 Proficiency deficiency: mastery of fundamental movement skills and skill
973 components in overweight and obese children. *Obesity (Silver Spring)* 20: 1024-
974 1033, 2012.

975 43. Cobley S, Baker J, Wattie N, and McKenna J. Annual age-grouping and
976 athlete development: a meta-analytical review of relative age effects in sport.
977 *Sports Med* 39: 235-256, 2009.

978 44. Cohen DD, Voss C, Taylor MJ, Delextrat A, Ogunleye AA, and Sandercock
979 GR. Ten-year secular changes in muscular fitness in English children. *Acta*
980 *Paediatr* 100: e175-177, 2011.

981 45. Comfort P, Stewart A, Bloom L, and Clarkson B. Relationships between
982 strength, sprint, and jump performance in well-trained youth soccer players. *J*
983 *Strength Cond Res* 28: 173-177, 2014.

984 46. Cools W, De Martelaer K, Vandaele B, Samaey C, and Andries C. Assessment
985 of Movement Skill Performance in Preschool Children: Convergent Validity
986 Between MOT 4-6 and M-ABC. *J Sports Sci Med* 9: 597-604, 2010.

987 47. Cools W, Martelaer KD, Samaey C, and Andries C. Movement skill
988 assessment of typically developing preschool children: a review of seven
989 movement skill assessment tools. *J Sports Sci Med* 8: 154-168, 2009.

990 48. Corder K, van Sluijs EM, Ridgway CL, Steele RM, Prynne CJ, Stephen AM,
991 Bamber DJ, Dunn VJ, Goodyer IM, and Ekelund U. Breakfast consumption and
992 physical activity in adolescents: daily associations and hourly patterns. *Am J Clin*
993 *Nutr* 99: 361-368, 2014.

994 49. Côté J, Baker J, and Abernethy B. Practice to play in the development of sport
995 expertise, in: *Handbook of Sport Psychology*. R Eklund, G Tenenbaum, eds.
996 Hoboken, NJ: Wiley, 2007, pp 184-202.

997 50. Côté J, Lidor R, and Hackfort D. ISSP position stand: to sample or to
998 specialize? Seven postulates about youth sport activities that lead to continued
999 participation and elite performance. *International Journal of Sport and Exercise*
1000 *Psychology* 9: 7-17, 2009.

1001 51. Crane J and Temple V. A systematic review of dropout from organized sport
1002 among children and youth. *Eur Phys Educ Rev*, in press.

52. Cuenca-Garcia M, Ruiz JR, Ortega FB, Labayen I, Gonzalez-Gross M, Moreno LA, Gomez-Martinez S, Ciarapica D, Hallstrom L, Wastlund A, Molnar D, Gottrand F, Manios Y, Widhalm K, Kafatos A, De Henauw S, Sjostrom M, Castillo MJ, and Group HS. Association of breakfast consumption with objectively measured and self-reported physical activity, sedentary time and physical fitness in European adolescents: the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. *Public Health Nutr* 17: 2226-2236, 2014.

53. Cunningham DJ, West DJ, Owen NJ, Shearer DA, Finn CV, Bracken RM, Crewther BT, Scott P, Cook CJ, and Kilduff LP. Strength and power predictors of sprinting performance in professional rugby players. *J Sports Med Phys Fitness* 53: 105-111, 2013.

54. D'Hondt E, Deforche B, Gentier I, De Bourdeaudhuij I, Vaeyens R, Philippaerts R, and Lenoir M. A longitudinal analysis of gross motor coordination in overweight and obese children versus normal-weight peers. *Int J Obes (Lond)* 37: 61-67, 2013.

55. D'Hondt E, Deforche B, Vaeyens R, Vandorpe B, Vandendriessche J, Pion J, Philippaerts R, de Bourdeaudhuij I, and Lenoir M. Gross motor coordination in relation to weight status and age in 5- to 12-year-old boys and girls: a cross-sectional study. *Int J Pediatr Obes* 6: e556-564, 2011.

56. De Ste Croix MB, Priestley AM, Lloyd RS, and Oliver JL. ACL injury risk in elite female youth soccer: Changes in neuromuscular control of the knee following soccer-specific fatigue. *Scand J Med Sci Sports*, 2014.

57. DiFiori JP, Benjamin HJ, Brenner J, Gregory A, Jayanthi N, Landry GL, and Luke A. Overuse injuries and burnout in youth sports: a position statement from the American Medical Society for Sports Medicine. *Clin J Sport Med* 24: 3-20, 2014.

58. DiFiori JP, Puffer JC, Aish B, and Dorey F. Wrist pain in young gymnasts: frequency and effects upon training over 1 year. *Clin J Sport Med* 12: 348-353, 2002.

59. Donaldson SJ and Ronan KR. The effects of sports participation on young adolescents' emotional well-being. *Adolescence* 41: 369-389, 2006.

60. Donath L, Faude O, Hagmann S, Roth R, and Zahner L. Fundamental movement skills in preschoolers: a randomized controlled trial targeting object control proficiency. *Child Care Health Dev*, 2015.

1038 61. Dotan R, Mitchell C, Cohen R, Gabriel D, Klentrou P, and Falk B. Child-adult
1039 differences in the kinetics of torque development. *J Sports Sci* 31: 945-953, 2013.

1040 62. Dotan R, Mitchell C, Cohen R, Klentrou P, Gabriel D, and Falk B. Child-adult
1041 differences in muscle activation--a review. *Pediatr Exerc Sci* 24: 2-21, 2012.

1042 63. Eime RM, Young JA, Harvey JT, Charity MJ, and Payne WR. A systematic
1043 review of the psychological and social benefits of participation in sport for
1044 children and adolescents: informing development of a conceptual model of health
1045 through sport. *Int J Behav Nutr Phys Act* 10: 98, 2013.

1046 64. Emery CA and Meeuwisse WH. The effectiveness of a neuromuscular
1047 prevention strategy to reduce injuries in youth soccer: a cluster-randomised
1048 controlled trial. *Br J Sports Med* 44: 555-562, 2010.

1049 65. Ericsson KA. Training history, deliberate practice and elite sports
1050 performance: an analysis in response to Tucker and Collins review--what makes
1051 champions? *Br J Sports Med* 47: 533-535, 2013.

1052 66. Ericsson KA, Krampe RT, and Tesch-Römer C. The role of deliberate practice
1053 in the acquisition of expert performance. *Psychol Rev* 100: 363-406, 1993.

1054 67. Faigenbaum AD, Farrell A, Fabiano M, Radler T, Naclerio F, Ratamess NA,
1055 Kang J, and Myer GD. Effects of integrative neuromuscular training on fitness
1056 performance in children. *Pediatr Exerc Sci* 23: 573-584, 2011.

1057 68. Faigenbaum AD, Kraemer WJ, Blimkie CJ, Jeffreys I, Micheli LJ, Nitka M,
1058 and Rowland TW. Youth resistance training: updated position statement paper
1059 from the national strength and conditioning association. *J Strength Cond Res* 23:
1060 S60-79, 2009.

1061 69. Faigenbaum AD, Lloyd RS, MacDonald J, and Myer GD. Citius, Altius,
1062 Fortius: beneficial effects of resistance training for young athletes. *Br J Sports*
1063 *Med*, 2015.

1064 70. Faigenbaum AD, Lloyd RS, and Myer GD. Youth resistance training: past
1065 practices, new perspectives, and future directions. *Pediatr Exerc Sci* 25: 591-604,
1066 2013.

1067 71. Faigenbaum AD, Lloyd RS, Sheehan D, and Myer GD. The role of the
1068 Pediatric Exercise Specialist in treating Exercise Deficit Disorder in youth.
1069 *Strength Cond J* 35: 34-41, 2013.

72. Faigenbaum AD, McFarland JE, Herman RE, Naclerio F, Ratamess NA, Kang J, and Myer GD. Reliability of the one-repetition-maximum power clean test in adolescent athletes. *J Strength Cond Res* 26: 432-437, 2012.

73. Faigenbaum AD, Milliken LA, and Westcott WL. Maximal strength testing in healthy children. *J Strength Cond Res* 17: 162-166, 2003.

74. Faigenbaum AD and Myer GD. Resistance training among young athletes: safety, efficacy and injury prevention effects. *Br J Sports Med* 44: 56-63, 2010.

75. Faigenbaum AD and Myer GD. Exercise deficit disorder in youth: play now or pay later. *Curr Sports Med Rep* 11: 196-200, 2012.

76. Faigenbaum AD, Stracciolini A, and Myer GD. Exercise deficit disorder in youth: a hidden truth. *Acta Paediatr* 100: 1423-1425; discussion 1425, 2011.

77. Falk B, Usselman C, Dotan R, Brunton L, Klentrou P, Shaw J, and Gabriel D. Child-adult differences in muscle strength and activation pattern during isometric elbow flexion and extension. *Appl Physiol Nutr Metab* 34: 609-615, 2009.

78. Feeley BT, Agel J, and LaPrade RF. When Is It Too Early for Single Sport Specialization? *Am J Sports Med*, 2015.

79. Ferguson B and Stern PJ. A case of early sports specialization in an adolescent athlete. *J Can Chiropr Assoc* 58: 377-383, 2014.

80. Ford KR, Myer GD, and Hewett TE. Valgus knee motion during landing in high school female and male basketball players. *Med Sci Sports Exerc* 35: 1745-1750, 2003.

81. Ford KR, Shapiro R, Myer GD, Van Den Bogert AJ, and Hewett TE. Longitudinal sex differences during landing in knee abduction in young athletes. *Med Sci Sports Exerc* 42: 1923-1931, 2010.

82. Ford P, De Ste Croix M, Lloyd R, Meyers R, Moosavi M, Oliver J, Till K, and Williams C. The long-term athlete development model: physiological evidence and application. *J Sports Sci* 29: 389-402, 2011.

83. Fransen J, Deprez D, Pion J, Tallir IB, D'Hondt E, Vaeyens R, Lenoir M, and Philippaerts RM. Changes in physical fitness and sports participation among children with different levels of motor competence: a 2-year longitudinal study. *Pediatr Exerc Sci* 26: 11-21, 2014.

84. Fransen J, Pion J, Vandendriessche J, Vandorpe B, Vaeyens R, Lenoir M, and Philippaerts RM. Differences in physical fitness and gross motor coordination in boys aged 6-12 years specializing in one versus sampling more than one sport. *J Sports Sci* 30: 379-386, 2012.

85. Fraser-Thomas J, Cote J, and Deakin J. Examining adolescent sport dropout and prolonged engagement from a developmental perspective. *J Appl Sport Psychol* 20: 318-333, 2008.

86. Fry AC, Irwin CC, Nicoll JX, and Ferebee DE. Muscular Strength and Power in 3-7 Year Old Children. *Pediatr Exerc Sci*, 2015.

87. Fuchs RK, Bauer JJ, and Snow CM. Jumping improves hip and lumbar spine bone mass in prepubescent children: a randomized controlled trial. *J Bone Miner Res* 16: 148-156, 2001.

88. Fuchs RK and Snow CM. Gains in hip bone mass from high-impact training are maintained: a randomized controlled trial in children. *J Pediatr* 141: 357-362, 2002.

89. Fukuda DH. Analysis of the Relative Age Effect in Elite Youth Judo Athletes. *Int J Sports Physiol Perform*, 2015.

90. Fullagar HH, Skorski S, Duffield R, Hammes D, Coutts AJ, and Meyer T. Sleep and athletic performance: the effects of sleep loss on exercise performance, and physiological and cognitive responses to exercise. *Sports Med* 45: 161-186, 2015.

91. Furley P and Memmert D. Coaches' implicit associations between size and giftedness: implications for the relative age effect. *J Sports Sci*: 1-8, 2015.

92. Gagné F. Constructs and models pertaining to exceptional human abilities, in: *International Handbook of Research and Development of Giftedness and Talent*. KA Heller, Monks, F.J., Passow, A.H., ed. Oxford, United Kingdom: Pergamon Press, 1993.

93. Gil SM, Badiola A, Bidaurrazaga-Letona I, Zabala-Lili J, Gravina L, Santos-Concejero J, Lekue JA, and Granados C. Relationship between the relative age effect and anthropometry, maturity and performance in young soccer players. *J Sports Sci* 32: 479-486, 2014.

94. Gokeler A, Benjaminse A, Hewett TE, Paterno MV, Ford KR, Otten E, and Myer GD. Feedback techniques to target functional deficits following anterior

1134 cruciate ligament reconstruction: implications for motor control and reduction of
1135 second injury risk. *Sports Med* 43: 1065-1074, 2013.

1136 95. Golley RK, Maher CA, Matricciani L, and Olds TS. Sleep duration or
1137 bedtime? Exploring the association between sleep timing behaviour, diet and BMI
1138 in children and adolescents. *Int J Obes (Lond)* 37: 546-551, 2013.

1139 96. Goncalves CE, Rama LM, and Figueiredo AB. Talent identification and
1140 specialization in sport: an overview of some unanswered questions. *Int J Sports*
1141 *Physiol Perform* 7: 390-393, 2012.

1142 97. Graham G, Holt/Hale SA, and Parker M. *Children Moving: A Reflective*
1143 *Approach to Teaching Physical Education.* New York, NY: McGraw Hill, 2013.

1144 98. Granacher U, Muehlbauer T, Doerflinger B, Strohmeier R, and Gollhofer A.
1145 Promoting strength and balance in adolescents during physical education: effects
1146 of a short-term resistance training. *J Strength Cond Res* 25: 940-949, 2011.

1147 99. Groslambert A, Hintzy F, Hoffman MD, Dugue B, and Rouillon JD.
1148 Validation of a rating scale of perceived exertion in young children. *Int J Sports*
1149 *Med* 22: 116-119, 2001.

1150 100. Guagliano JM, Rosenkranz RR, and Kolt GS. Girls' physical activity levels
1151 during organized sports in Australia. *Med Sci Sports Exerc* 45: 116-122, 2013.

1152 101. Gulbin J, Weissensteiner J, Oldenziel K, and Gagne F. Patterns of
1153 performance development in elite athletes. *Eur J Sport Sci* 13: 605-614, 2013.

1154 102. Gutierrez M and Ruiz LM. Perceived motivational climate, sportsmanship,
1155 and students' attitudes toward physical education classes and teachers. *Percept*
1156 *Mot Skills* 108: 308-326, 2009.

1157 103. Haff GG. Periodization strategies for youth development, in: *Strength and*
1158 *Conditioning for Young Athletes: Science and Application*. RS Lloyd, JL Oliver,
1159 eds. Oxford, United Kingdom: Routledge, 2013, pp 149-168.

1160 104. Hall R, Barber Foss K, Hewett TE, and Myer GD. Sport specialization's
1161 association with an increased risk of developing anterior knee pain in adolescent
1162 female athletes. *J Sport Rehabil* 24: 31-35, 2015.

105. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U, and Lancet Physical Activity Series Working G. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet* 380: 247-257, 2012.

106. Halson SL. Monitoring training load to understand fatigue in athletes. *Sports Med* 44 Suppl 2: S139-147, 2014.

107. Hardy LL, Reinten-Reynolds T, Espinel P, Zask A, and Okely AD. Prevalence and correlates of low fundamental movement skill competency in children. *Pediatrics* 130: e390-398, 2012.

108. Harries SK, Lubans DR, and Callister R. Resistance training to improve power and sports performance in adolescent athletes: a systematic review and meta-analysis. *J Sci Med Sport* 15: 532-540, 2012.

109. Hewett TE, Ford KR, and Myer GD. Anterior cruciate ligament injuries in female athletes: Part 2, a meta-analysis of neuromuscular interventions aimed at injury prevention. *Am J Sports Med* 34: 490-498, 2006.

110. Hewett TE, Lindenfeld TN, Riccobene JV, and Noyes FR. The effect of neuromuscular training on the incidence of knee injury in female athletes. A prospective study. *Am J Sports Med* 27: 699-706, 1999.

111. Hewett TE, Myer GD, and Ford KR. Decrease in neuromuscular control about the knee with maturation in female athletes. *J Bone Joint Surg Am* 86-A: 1601-1608, 2004.

112. Hewett TE, Myer GD, Ford KR, Heidt RS, Jr., Colosimo AJ, McLean SG, van den Bogert AJ, Paterno MV, and Succop P. Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. *Am J Sports Med* 33: 492-501, 2005.

113. Hewett TE, Myer GD, Kiefer AW, and Ford KR. Longitudinal Increases in Knee Abduction Moments in Females during Adolescent Growth. *Med Sci Sports Exerc*, 2015.

114. Hills AP, Andersen LB, and Byrne NM. Physical activity and obesity in children. *Br J Sports Med* 45: 866-870, 2011.

115. Hills AP, Okely AD, and Baur LA. Addressing childhood obesity through increased physical activity. *Nat Rev Endocrinol* 6: 543-549, 2010.

116. Hind K and Burrows M. Weight-bearing exercise and bone mineral accrual in children and adolescents: a review of controlled trials. *Bone* 40: 14-27, 2007.

117. Huppert FA, Baylis N, and Keverne B. Introduction: why do we need a science of well-being? *Philos Trans R Soc Lond B Biol Sci* 359: 1331-1332, 2004.

118. Jackowski SA, Baxter-Jones AD, Gruodyte-Raciene R, Kontulainen SA, and Erlandson MC. A longitudinal study of bone area, content, density, and strength development at the radius and tibia in children 4-12 years of age exposed to recreational gymnastics. *Osteoporos Int* 26: 1677-1690, 2015.

119. Jayanthi N, Pinkham C, Dugas L, Patrick B, and Labella C. Sports specialization in young athletes: evidence-based recommendations. *Sports Health* 5: 251-257, 2013.

120. Jayanthi NA, LaBella CR, Fischer D, Pasulka J, and Dugas LR. Sports-specialized intensive training and the risk of injury in young athletes: a clinical case-control study. *Am J Sports Med* 43: 794-801, 2015.

121. Johnson BA, Salzberg CL, and Stevenson DA. A systematic review: plyometric training programs for young children. *J Strength Cond Res* 25: 2623-2633, 2011.

122. Jullien H, Bisch C, Largouet N, Manouvrier C, Carling CJ, and Amiard V. Does a short period of lower limb strength training improve performance in field-based tests of running and agility in young professional soccer players? *J Strength Cond Res* 22: 404-411, 2008.

123. Junge A, Rosch D, Peterson L, Graf-Baumann T, and Dvorak J. Prevention of soccer injuries: a prospective intervention study in youth amateur players. *Am J Sports Med* 30: 652-659, 2002.

124. Karageorghis C and Terry P. *Inside Sport Psychology.* Champaign, IL: Human Kinetics, 2011.

125. Keiner M, Sander A, Wirth K, Caruso O, Immesberger P, and Zawieja M. Strength performance in youth: trainability of adolescents and children in the back and front squats. *J Strength Cond Res* 27: 357-362, 2013.

126. Keiner M, Sander A, Wirth K, and Schmidtbleicher D. Long-term strength training effects on change-of-direction sprint performance. *J Strength Cond Res* 28: 223-231, 2014.

127. Kentta G, Hassmen P, and Raglin JS. Training practices and overtraining syndrome in Swedish age-group athletes. *Int J Sports Med* 22: 460-465, 2001.

128. Kernozek TW, Torry MR, and Iwasaki M. Gender differences in lower extremity landing mechanics caused by neuromuscular fatigue. *Am J Sports Med* 36: 554-565, 2008.

129. Kerr G. Physical and emotional abuse of elite child athletes: the case of forced physical exertion, in: *Elite Child Athlete Welfare: International Perspectives*. CH Brackenridge, D Rhind, eds. London: Brunel University Press, 2010.

130. Kerssemakers SP, Fotiadou AN, de Jonge MC, Karantanas AH, and Maas M. Sport injuries in the paediatric and adolescent patient: a growing problem. *Pediatr Radiol* 39: 471-484, 2009.

131. Kölling S, Hitzschke B, Holst T, Ferrauti A, Meyer T, Pfeiffer M, and Kellman M. Validity of the acute recovery and stress scale: training monitoring of the German junior national field hockey team. *Int J Sports Sci Coach* 10: 529-542, 2015.

132. Krosshaug T, Nakamae A, Boden BP, Engebretsen L, Smith G, Slauterbeck JR, Hewett TE, and Bahr R. Mechanisms of anterior cruciate ligament injury in basketball: video analysis of 39 cases. *Am J Sports Med* 35: 359-367, 2007.

133. Kubo K, Teshima T, Ikebukuro T, Hirose N, and Tsunoda N. Tendon properties and muscle architecture for knee extensors and plantar flexors in boys and men. *Clin Biomech (Bristol, Avon)* 29: 506-511, 2014.

134. Kushner AM, Kiefer AW, Lesnick S, Faigenbaum AD, Kashikar-Zuck S, and Myer GD. Training the developing brain part II: cognitive considerations for youth instruction and feedback. *Curr Sports Med Rep* 14: 235-243, 2015.

135. Lai SK, Costigan SA, Morgan PJ, Lubans DR, Stodden DF, Salmon J, and Barnett LM. Do school-based interventions focusing on physical activity, fitness, or fundamental movement skill competency produce a sustained impact in these outcomes in children and adolescents? A systematic review of follow-up studies. *Sports Med* 44: 67-79, 2014.

136. Leek D, Carlson JA, Cain KL, Henrichon S, Rosenberg D, Patrick K, and Sallis JF. Physical activity during youth sports practices. *Arch Pediatr Adolesc Med* 165: 294-299, 2011.

137. Leipold B and Greve W. Resilience: a conceptual bridge between coping and development. *Eur Psychol* 14: 40-50, 2009.

138. Lemos AG, Avigo EL, and Barela JA. Physical education in kindergarten promotes fundamental motor skill development. *Adv Phys Educ* 2: 17-21, 2012.

139. Lexell J, Sjostrom M, Nordlund AS, and Taylor CC. Growth and development of human muscle: a quantitative morphological study of whole vastus lateralis from childhood to adult age. *Muscle Nerve* 15: 404-409, 1992.

140. Lloyd M, Saunders TJ, Bremer E, and Tremblay MS. Long-term importance of fundamental motor skills: a 20-year follow-up study. *Adapt Phys Activ Q* 31: 67-78, 2014.

141. Lloyd RS, Faigenbaum AD, Stone MH, Oliver JL, Jeffreys I, Moody JA, Brewer C, Pierce KC, McCambridge TM, Howard R, Herrington L, Hainline B, Micheli LJ, Jaques R, Kraemer WJ, McBride MG, Best TM, Chu DA, Alvar BA, and Myer GD. Position statement on youth resistance training: the 2014 International Consensus. *Br J Sports Med* 48: 498-505, 2014.

142. Lloyd RS and Oliver JL. The youth physical development model: a new approach to long-term athletic development. *Strength Cond J* 34: 61-72, 2012.

143. Lloyd RS, Oliver JL, Faigenbaum AD, Howard R, De Ste Croix MB, Williams CA, Best TM, Alvar BA, Micheli LJ, Thomas DP, Hatfield DL, Cronin JB, and Myer GD. Long-term athletic development- part 1: a pathway for all youth. *J Strength Cond Res* 29: 1439-1450, 2015.

144. Lloyd RS, Oliver JL, Faigenbaum AD, Howard R, De Ste Croix MB, Williams CA, Best TM, Alvar BA, Micheli LJ, Thomas DP, Hatfield DL, Cronin JB, and Myer GD. Long-term athletic development, part 2: barriers to success and potential solutions. *J Strength Cond Res* 29: 1451-1464, 2015.

145. Lloyd RS, Oliver JL, Faigenbaum AD, Myer GD, and De Ste Croix MB. Chronological age vs. biological maturation: implications for exercise programming in youth. *J Strength Cond Res* 28: 1454-1464, 2014.

146. Lloyd RS, Oliver JL, Meyers RW, Moody JA, and Stone MH. Long-term athletic development and its application to youth weightlifting. *Strength Cond J* 34: 55-66, 2012.

147. Lloyd RS, Radnor JM, De Ste Croix MBA, Cronin JB, and Oliver JL. Changes in sprint and jump performance in response to different modes of

ressitance training in boys, pre- and post-peak height velocity. *J Strength Cond Res*, in press.

148. Low LK and Cheng HJ. Axon pruning: an essential step underlying the developmental plasticity of neuronal connections. *Philos Trans R Soc Lond B Biol Sci* 361: 1531-1544, 2006.

149. Lubans DR, Morgan PJ, Cliff DP, Barnett LM, and Okely AD. Fundamental movement skills in children and adolescents: review of associated health benefits. *Sports Med* 40: 1019-1035, 2010.

150. Luke A, Lazaro RM, Bergeron MF, Keyser L, Benjamin H, Brenner J, d'Hemecourt P, Grady M, Philpott J, and Smith A. Sports-related injuries in youth athletes: is overscheduling a risk factor? *Clin J Sport Med* 21: 307-314, 2011.

151. Malina RM. Early sport specialization: roots, effectiveness, risks. *Curr Sports Med Rep* 9: 364-371, 2010.

152. Malina RM. Physical activity as a factor in growth and maturation., in: *Human Growth and Development*. N Cameron, B Bogin, eds. Waltham, MA: Academic Press, 2012, pp 375-396.

153. Malina RM, Baxter-Jones AD, Armstrong N, Beunen GP, Caine D, Daly RM, Lewis RD, Rogol AD, and Russell K. Role of intensive training in the growth and maturation of artistic gymnasts. *Sports Med* 43: 783-802, 2013.

154. Malina RM, Coelho ESMJ, Figueiredo AJ, Carling C, and Beunen GP. Interrelationships among invasive and non-invasive indicators of biological maturation in adolescent male soccer players. *J Sports Sci* 30: 1705-1717, 2012.

155. Malina RM, Eisenmann JC, Cumming SP, Ribeiro B, and Aroso J. Maturity-associated variation in the growth and functional capacities of youth football (soccer) players 13-15 years. *Eur J Appl Physiol* 91: 555-562, 2004.

156. Malina RM, Rogol AD, Cumming SP, Coelho ESMJ, and Figueiredo AJ. Biological maturation of youth athletes: assessment and implications. *Br J Sports Med* 49: 852-859, 2015.

157. Malina RMB, C.; Bar-Or, O. *Growth, Maturation and Physical Activity*. Champaign, IL: Human Kinetics, 2004.

158. Mandelbaum BR, Silvers HJ, Watanabe DS, Knarr JF, Thomas SD, Griffin LY, Kirkendall DT, and Garrett W, Jr. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. *Am J Sports Med* 33: 1003-1010, 2005.

159. Mann JB, Bryant K, Johnstone B, Ivey P, and Sayers SP. The effect of physical and academic stress on illness and injury in division 1 college football players. *J Strength Cond Res*, 2015.

160. Matina RM and Rogol AD. Sport training and the growth and pubertal maturation of young athletes. *Pediatr Endocrinol Rev* 9: 441-455, 2011.

161. Matos N and Winsley RJ. Trainability of young athletes and overtraining. *J Sports Sci Med* 6: 353-367, 2007.

162. Matos NF, Winsley RJ, and Williams CA. Prevalence of nonfunctional overreaching/overtraining in young English athletes. *Med Sci Sports Exerc* 43: 1287-1294, 2011.

163. Matricciani L, Olds T, and Petkov J. In search of lost sleep: secular trends in the sleep time of school-aged children and adolescents. *Sleep Med Rev* 16: 203-211, 2012.

164. McCarthy N and Collins D. Initial identification & selection bias versus the eventual confirmation of talent: evidence for the benefits of a rocky road? *J Sports Sci* 32: 1604-1610, 2014.

165. McHugh MP. Oversized young athletes: a weighty concern. *Br J Sports Med* 44: 45-49, 2010.

166. McLean BD, Coutts AJ, Kelly V, McGuigan MR, and Cormack SJ. Neuromuscular, endocrine, and perceptual fatigue responses during different length between-match microcycles in professional rugby league players. *Int J Sports Physiol Perform* 5: 367-383, 2010.

167. McLean SG, Fellin RE, Suedekum N, Calabrese G, Passerallo A, and Joy S. Impact of fatigue on gender-based high-risk landing strategies. *Med Sci Sports Exerc* 39: 502-514, 2007.

168. McNarry M and Jones A. The influence of training status on the aerobic and anaerobic responses to exercise in children: a review. *Eur J Sport Sci* 14 Suppl 1: S57-68, 2014.

169. Meeusen R, Duclos M, Foster C, Fry A, Gleeson M, Nieman D, Raglin J, Rietjens G, Steinacker J, Urhausen A, European College of Sport S, and American College of Sports M. Prevention, diagnosis, and treatment of the overtraining syndrome: joint consensus statement of the European College of Sport Science and the American College of Sports Medicine. *Med Sci Sports Exerc* 45: 186-205, 2013.

170. Meyers RW, Oliver J, Lloyd RS, Hughes M, and Cronin J. Reliability of the Spatio-Temporal Determinants of Maximal Sprint Speed in Adolescent Boys Over Single and Multiple Steps. *Pediatr Exerc Sci*, 2015.

171. Meylan C and Malatesta D. Effects of in-season plyometric training within soccer practice on explosive actions of young players. *J Strength Cond Res* 23: 2605-2613, 2009.

172. Micheli LJ and Natsis KI. Preventing injuries in team sports: what the team physician needs to know, in: *FIMS Team Physician Manual (3rd Edition)*. LJ Micheli, F Pigozzi, KM Chan, WR Frontera, N Bachl, AD Smith, ST Alenabi, eds. London: Routledge, 2013, pp 505-520.

173. Milliken LA, Faigenbaum AD, Loud RL, and Westcott WL. Correlates of upper and lower body muscular strength in children. *J Strength Cond Res* 22: 1339-1346, 2008.

174. Moesch K, Elbe AM, Hauge ML, and Wikman JM. Late specialization: the key to success in centimeters, grams, or seconds (cgs) sports. *Scand J Med Sci Sports* 21: e282-290, 2011.

175. Moliner-Urdiales D, Ruiz JR, Ortega FB, Jimenez-Pavon D, Vicente-Rodriguez G, Rey-Lopez JP, Martinez-Gomez D, Casajus JA, Mesana MI, Marcos A, Noriega-Borge MJ, Sjostrom M, Castillo MJ, Moreno LA, Avena, and Groups HS. Secular trends in health-related physical fitness in Spanish adolescents: the AVENA and HELENA studies. *J Sci Med Sport* 13: 584-588, 2010.

176. Mostafavifar AM, Best TM, and Myer GD. Early sport specialisation, does it lead to long-term problems? *Br J Sports Med* 47: 1060-1061, 2013.

177. Mountjoy M, Armstrong N, Bizzini L, Blimkie C, Evans J, Gerrard D, Hangen J, Knoll K, Micheli L, Sangenis P, and Van Mechelen W. IOC consensus statement: "training the elite child athlete". *Br J Sports Med* 42: 163-164, 2008.

178. Mountjoy M, Rhind DJ, Tiivas A, and Leglise M. Safeguarding the child athlete in sport: a review, a framework and recommendations for the IOC youth athlete development model. *Br J Sports Med* 49: 883-886, 2015.

179. Must A and Tybor DJ. Physical activity and sedentary behavior: a review of longitudinal studies of weight and adiposity in youth. *Int J Obes (Lond)* 29 Suppl 2: S84-96, 2005.

180. Myer GD, Faigenbaum AD, Chu DA, Falkel J, Ford KR, Best TM, and Hewett TE. Integrative training for children and adolescents: techniques and practices for reducing sports-related injuries and enhancing athletic performance. *Phys Sportsmed* 39: 74-84, 2011.

181. Myer GD, Faigenbaum AD, Edwards NM, Clark JF, Best TM, and Sallis RE. Sixty minutes of what? A developing brain perspective for activating children with an integrative exercise approach. *Br J Sports Med*, 2015.

182. Myer GD, Faigenbaum AD, Ford KR, Best TM, Bergeron MF, and Hewett TE. When to initiate integrative neuromuscular training to reduce sports-related injuries and enhance health in youth? *Curr Sports Med Rep* 10: 155-166, 2011.

183. Myer GD, Faigenbaum AD, Stracciolini A, Hewett TE, Micheli LJ, and Best TM. Exercise deficit disorder in youth: a paradigm shift toward disease prevention and comprehensive care. *Curr Sports Med Rep* 12: 248-255, 2013.

184. Myer GD, Ford KR, Brent JL, and Hewett TE. The effects of plyometric vs. dynamic stabilization and balance training on power, balance, and landing force in female athletes. *J Strength Cond Res* 20: 345-353, 2006.

185. Myer GD, Ford KR, Divine JG, Wall EJ, Kahanov L, and Hewett TE. Longitudinal assessment of noncontact anterior cruciate ligament injury risk factors during maturation in a female athlete: a case report. *J Athl Train* 44: 101-109, 2009.

186. Myer GD, Jayanthi N, DiFiori JP, Faigenbaum AD, Kiefer AW, Logerstedt D, and Micheli LJ. Alternative solutions to early sport specialization in young athletes. *Sports Health*, in press.

187. Myer GD, Jayanthi N, DiFiori JP, Faigenbaum AD, Kiefer AW, Logerstedt D, and Micheli LJ. Sport specialization, part 1: does early sports specialization increase negative outcomes and reduce the opportunity for success in young athletes? *Sports Health*, in press.

188. Myer GD, Kushner AM, Faigenbaum AD, Kiefer A, Kashikar-Zuck S, and Clark JF. Training the developing brain, part I: cognitive developmental considerations for training youth. *Curr Sports Med Rep* 12: 304-310, 2013.

189. Myer GD, Lloyd RS, Brent JL, and Faigenbaum AD. How Young is "Too Young" to Start Training? *ACSMs Health Fit J* 17: 14-23, 2013.

190. Myer GD, Sugimoto D, Thomas S, and Hewett TE. The influence of age on the effectiveness of neuromuscular training to reduce anterior cruciate ligament injury in female athletes: a meta-analysis. *Am J Sports Med* 41: 203-215, 2013.

191. Nader PR, Bradley RH, Houts RM, McRitchie SL, and O'Brien M. Moderate-to-vigorous physical activity from ages 9 to 15 years. *JAMA* 300: 295-305, 2008.

192. Nyland J. Coming to terms with early sports specialization and athletic injuries. *J Orthop Sports Phys Ther* 44: 389-390, 2014.

193. O'Brien TD, Reeves ND, Baltzopoulos V, Jones DA, and Maganaris CN. Muscle-tendon structure and dimensions in adults and children. *J Anat* 216: 631-642, 2010.

194. Ogden CL, Carroll MD, Kit BK, and Flegal KM. Prevalence of obesity and trends in body mass index among US children and adolescents, 1999-2010. *JAMA* 307: 483-490, 2012.

195. Okely AD and Booth ML. Mastery of fundamental movement skills among children in New South Wales: prevalence and sociodemographic distribution. *J Sci Med Sport* 7: 358-372, 2004.

196. Oliver JL, Brady A, and Lloyd RS. Well-being of youth athletes, in: *Strength and Conditioning for Young Athletes: Science and Application*. RS Lloyd, JL Oliver, eds. Oxon: Routledge, 2013, pp 213-225.

197. Oliver JL, Lloyd RS, and Meyers RW. Training elite child athletes: promoting welfare and well-being. *Strength Cond J* 33: 73-79, 2011.

198. Oliver JL and Smith PM. Neural control of leg stiffness during hopping in boys and men. *J Electromyogr Kinesiol* 20: 973-979, 2010.

199. Oliver JL, Whitney A, and Lloyd RS. Monitoring of in-season neuromuscular and perceptual fatigue in youth rugby players. *Eur J Sport Sci*, in press.

200. Olsen SJ, 2nd, Fleisig GS, Dun S, Loftice J, and Andrews JR. Risk factors for shoulder and elbow injuries in adolescent baseball pitchers. *Am J Sports Med* 34: 905-912, 2006.

201. Ommundsen Y, Roberts GC, Lemyre PN, and Miller BW. Parental and coach support or pressure on psychosocial outcomes of pediatric athletes in soccer. *Clin J Sport Med* 16: 522-526, 2006.

202. Padua DA, Arnold BL, Perrin DH, Gansneder BM, Carcia CR, and Granata KP. Fatigue, vertical leg stiffness, and stiffness control strategies in males and females. *J Athl Train* 41: 294-304, 2006.

203. Painter KB, Haff GG, Ramsey MW, McBride J, Triplett T, Sands WA, Lamont HS, Stone ME, and Stone MH. Strength gains: block versus daily undulating periodization weight training among track and field athletes. *Int J Sports Physiol Perform* 7: 161-169, 2012.

204. Pearson DT, Naughton GA, and Torode M. Predictability of physiological testing and the role of maturation in talent identification for adolescent team sports. *J Sci Med Sport* 9: 277-287, 2006.

205. Philippaerts RM, Vaeyens R, Janssens M, Van Renterghem B, Matthys D, Craen R, Bourgois J, Vrijens J, Beunen G, and Malina RM. The relationship between peak height velocity and physical performance in youth soccer players. *J Sports Sci* 24: 221-230, 2006.

206. Plisk SS and Stone MH. Periodization strategies. *Strength Cond J* 25: 19-37, 2003.

207. Quatman CE, Ford KR, Myer GD, and Hewett TE. Maturation leads to gender differences in landing force and vertical jump performance: a longitudinal study. *Am J Sports Med* 34: 806-813, 2006.

208. Quatman-Yates CC, Myer GD, Ford KR, and Hewett TE. A longitudinal evaluation of maturational effects on lower extremity strength in female adolescent athletes. *Pediatr Phys Ther* 25: 271-276, 2013.

209. Quatman-Yates CC, Quatman CE, Meszaros AJ, Paterno MV, and Hewett TE. A systematic review of sensorimotor function during adolescence: a

1483 developmental stage of increased motor awkwardness? *Br J Sports Med* 46: 649-
1484 655, 2012.

1485 210. Raglin J, Sawamura S, Alexiou S, Hassmen P, and Kentta G. Training
1486 practices and staleness in 13-18-year-old swimmers: a cross-cultural study.
1487 *Pediatr Exerc Sci* 12: 61-70, 2000.

1488 211. Ratel S, Duche P, and Williams CA. Muscle fatigue during high-intensity
1489 exercise in children. *Sports Med* 36: 1031-1065, 2006.

1490 212. Ratel S, Williams CA, Oliver J, and Armstrong N. Effects of age and
1491 recovery duration on performance during multiple treadmill sprints. *Int J Sports*
1492 *Med* 27: 1-8, 2006.

1493 213. Reddy LA, Fabiano GA, Dudek CM, and Hsu L. Instructional and behavior
1494 management practices implemented by elementary general education teachers. *J*
1495 *Sch Psychol* 51: 683-700, 2013.

1496 214. Robinson LE, Stodden DF, Barnett LM, Lopes VP, Logan SW, Rodrigues
1497 LP, and D'Hondt E. Motor Competence and its Effect on Positive Developmental
1498 Trajectories of Health. *Sports Med* 45: 1273-1284, 2015.

1499 215. Rogasch NC, Dartnall TJ, Cirillo J, Nordstrom MA, and Semmler JG.
1500 Corticomotor plasticity and learning of a ballistic thumb training task are
1501 diminished in older adults. *J Appl Physiol (1985)* 107: 1874-1883, 2009.

1502 216. Rose MS, Emery CA, and Meeuwisse WH. Sociodemographic predictors of
1503 sport injury in adolescents. *Med Sci Sports Exerc* 40: 444-450, 2008.

1504 217. Rossler R, Donath L, Verhagen E, Junge A, Schweizer T, and Faude O.
1505 Exercise-based injury prevention in child and adolescent sport: a systematic
1506 review and meta-analysis. *Sports Med* 44: 1733-1748, 2014.

1507 218. Rumpf MC, Cronin JB, Oliver JL, and Hughes M. Assessing youth sprint
1508 ability-methodological issues, reliability and performance data. *Pediatr Exerc Sci*
1509 23: 442-467, 2011.

1510 219. Rumpf MC, Cronin JB, Pinder SD, Oliver J, and Hughes M. Effect of
1511 different training methods on running sprint times in male youth. *Pediatr Exerc*
1512 *Sci* 24: 170-186, 2012.

220. Runhaar J, Collard DC, Singh AS, Kemper HC, van Mechelen W, and Chinapaw M. Motor fitness in Dutch youth: differences over a 26-year period (1980-2006). *J Sci Med Sport* 13: 323-328, 2010.

221. Ryan RM and Deci EL. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am Psychol* 55: 68-78, 2000.

222. Sallis JF, Prochaska JJ, and Taylor WC. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc* 32: 963-975, 2000.

223. Salvy SJ, de la Haye K, Bowker JC, and Hermans RC. Influence of peers and friends on children's and adolescents' eating and activity behaviors. *Physiol Behav* 106: 369-378, 2012.

224. Sander A, Keiner M, Wirth K, and Schmidtbleicher D. Influence of a 2-year strength training programme on power performance in elite youth soccer players. *Eur J Sport Sci* 13: 445-451, 2013.

225. Sandercock GR, Ogunleye AA, Parry DA, Cohen DD, Taylor MJ, and Voss C. Athletic performance and birth month: is the relative age effect more than just selection bias? *Int J Sports Med* 35: 1017-1023, 2014.

226. Sandercock GR, Taylor MJ, Voss C, Ogunleye AA, Cohen DD, and Parry DA. Quantification of the relative age effect in three indices of physical performance. *J Strength Cond Res* 27: 3293-3299, 2013.

227. Saracci R. The World Health Organisation needs to reconsider its definition of health. *BMJ* 314: 1409-1410, 1997.

228. Schmikli SL, de Vries WR, Inklaar H, and Backx FJ. Injury prevention target groups in soccer: injury characteristics and incidence rates in male junior and senior players. *J Sci Med Sport* 14: 199-203, 2011.

229. Schranz N, Tomkinson G, and Olds T. What is the effect of resistance training on the strength, body composition and psychosocial status of overweight and obese children and adolescents? A Systematic review and meta-analysis. *Sports Med* 43: 893-907, 2013.

230. Schranz N, Tomkinson G, Parletta N, Petkov J, and Olds T. Can resistance training change the strength, body composition and self-concept of overweight and obese adolescent males? A randomised controlled trial. *Br J Sports Med* 48: 1482-1488, 2014.

231. Shaibi GQ, Cruz ML, Ball GD, Weigensberg MJ, Salem GJ, Crespo NC, and Goran MI. Effects of resistance training on insulin sensitivity in overweight Latino adolescent males. *Med Sci Sports Exerc* 38: 1208-1215, 2006.

232. Smith RE, Smoll FL, and Cumming SP. Effects of a motivational climate inntervention for coaches on young athletes' sport performance anxiety. *J Sport Exerc Psychol* 29: 39-59, 2007.

233. Smith RE, Smoll FL, and Cumming SP. Motivational climate and changes in young athletes' achievement goal orientations. *Motiv Emot* 33: 173-183, 2009.

234. Smoll FL, Cumming SP, and Smith RE. Enhancing coach-parent relationships in youth sports: increasing harmony and minimzing hassle. *Int J Sports Sci Coach* 6: 13-26, 2011.

235. Smucny M, Parikh SN, and Pandya NK. Consequences of single sport specialization in the pediatric and adolescent athlete. *Orthop Clin North Am* 46: 249-258, 2015.

236. Soligard T, Myklebust G, Steffen K, Holme I, Silvers H, Bizzini M, Junge A, Dvorak J, Bahr R, and Andersen TE. Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. *BMJ* 337: a2469, 2008.

237. Sowell ER, Thompson PM, Leonard CM, Welcome SE, Kan E, and Toga AW. Longitudinal mapping of cortical thickness and brain growth in normal children. *J Neurosci* 24: 8223-8231, 2004.

238. Sowell ER, Trauner DA, Gamst A, and Jernigan TL. Development of cortical and subcortical brain structures in childhood and adolescence: a structural MRI study. *Dev Med Child Neurol* 44: 4-16, 2002.

239. Stein CJ and Micheli LJ. Overuse injuries in youth sports. *Phys Sportsmed* 38: 102-108, 2010.

240. Steptoe A and Butler N. Sports participation and emotional wellbeing in adolescents. *Lancet* 347: 1789-1792, 1996.

241. Stiles J and Jernigan TL. The basics of brain development. *Neuropsychol Rev* 20: 327-348, 2010.

242. Stodden DF, Gao Z, Goodway JD, and Langendorfer SJ. Dynamic relationships between motor skill competence and health-related fitness in youth. *Pediatr Exerc Sci* 26: 231-241, 2014.

243. Stovitz SD and Johnson RJ. "Underuse" as a cause for musculoskeletal injuries: is it time that we started reframing our message? *Br J Sports Med* 40: 738-739, 2006.

244. Stratton G and Williams CA. Children and fitness testing, in: *Sport and Exericse Physiology Testing Guidelines*. EM Winter, AM Jones, RCR Davison, PD Bromley, TH Mercer, eds. Oxon: Routledge, pp 211-223.

245. Sugimoto D, Myer GD, Foss KD, and Hewett TE. Dosage effects of neuromuscular training intervention to reduce anterior cruciate ligament injuries in female athletes: meta- and sub-group analyses. *Sports Med* 44: 551-562, 2014.

246. Swart E, Redler L, Fabricant PD, Mandelbaum BR, Ahmad CS, and Wang YC. Prevention and screening programs for anterior cruciate ligament injuries in young athletes: a cost-effectiveness analysis. *J Bone Joint Surg Am* 96: 705-711, 2014.

247. Ten Hoor GA, Plasqui G, Ruiter RA, Kremers SP, Rutten GM, Schols AM, and Kok G. A new direction in psychology and health: Resistance exercise training for obese children and adolescents. *Psychol Health*: 1-8, 2015.

248. Tenforde AS, Sayres LC, McCurdy ML, Collado H, Sainani KL, and Fredericson M. Overuse injuries in high school runners: lifetime prevalence and prevention strategies. *PM R* 3: 125-131; quiz 131, 2011.

249. Terry PC, Lane AM, Lane HJ, and Keohane L. Development and validation of a mood measure for adolescents. *J Sports Sci* 17: 861-872, 1999.

250. Tibana RA, Prestes J, Nascimento Dda C, Martins OV, De Santana FS, and Balsamo S. Higher muscle performance in adolescents compared with adults after a resistance training session with different rest intervals. *J Strength Cond Res* 26: 1027-1032, 2012.

251. Tofler IR, Knapp PK, and Larden M. Achievement by proxy distortion in sports: a distorted mentoring of high-achieving youth. Historical perspectives and clinical intervention with children, adolescents, and their families. *Clin Sports Med* 24: 805-828, viii, 2005.

252. Tremblay MS, Gray CE, Akinroye K, Harrington DM, Katzmarzyk PT, Lambert EV, Liukkonen J, Maddison R, Ocansey RT, Onywera VO, Prista A, Reilly JJ, Rodriguez Martinez MP, Sarmiento Duenas OL, Standage M, and Tomkinson G. Physical activity of children: a global matrix of grades comparing 15 countries. *J Phys Act Health* 11 Suppl 1: S113-125, 2014.

253. Tremblay MS and Willms JD. Is the Canadian childhood obesity epidemic related to physical inactivity? *Int J Obes Relat Metab Disord* 27: 1100-1105, 2003.

254. Tudor-Locke C, Johnson WD, and Katzmarzyk PT. Accelerometer-determined steps per day in US children and youth. *Med Sci Sports Exerc* 42: 2244-2250, 2010.

255. Vaeyens R, Lenoir M, Williams AM, and Philippaerts RM. Talent identification and development programmes in sport : current models and future directions. *Sports Med* 38: 703-714, 2008.

256. Valovich McLeod TC, Decoster LC, Loud KJ, Micheli LJ, Parker JT, Sandrey MA, and White C. National Athletic Trainers' Association position statement: prevention of pediatric overuse injuries. *J Athl Train* 46: 206-220, 2011.

257. van Beurden E, Zask A, Barnett LM, and Dietrich UC. Fundamental movement skills--how do primary school children perform? The 'Move it Groove it' program in rural Australia. *J Sci Med Sport* 5: 244-252, 2002.

258. van der Sluis A, Elferink-Gemser MT, Coelho-e-Silva MJ, Nijboer JA, Brink MS, and Visscher C. Sport injuries aligned to peak height velocity in talented pubertal soccer players. *Int J Sports Med* 35: 351-355, 2014.

259. Van Praagh E and Dore E. Short-term muscle power during growth and maturation. *Sports Med* 32: 701-728, 2002.

260. Vealey RN and Chase MA. Self-confidence in sport, in: *Advances in Sport Psychology, 3rd ed*. TS Horn, ed. Champaign, IL: Human Kinetics, 2008.

261. Viru A, Loko J, Harro M, Volver A, Laaneot L, and Viru M. Critical periods in the development of performance capacity during childhood and adolescence. *European Journal of Physical Education* 4: 75-119, 1999.

262. Waugh CM, Korff T, Fath F, and Blazevich AJ. Rapid force production in children and adults: mechanical and neural contributions. *Med Sci Sports Exerc* 45: 762-771, 2013.

263. Welsman JR and Armstrong N. The measurement and interpretation of aerobic fitness in children: current issues. *J R Soc Med* 89: 281P-285P, 1996.

264. WHO. World Health Organisation - Global recommendations on physical activity for health. Geneva, 2010.

265. Wiersma LD. Risks and benefits of youth sport specialization: perspectives and recommendations. *Pediatr Exerc Sci* 12: 13-22, 2000.

266. Winter EM and Cobb M. Ethics in paediatric research, in: *Paediatric Exercise Science and Medicine, 2nd ed*. N Armstrong, W Van Mechelen, eds. Oxford: Oxford University Press, 2008, pp 3-12.

267. Witzke KA and Snow CM. Effects of plyometric jump training on bone mass in adolescent girls. *Med Sci Sports Exerc* 32: 1051-1057, 2000.

268. Wojtys EM. Sports Specialization vs Diversification. *Sports Health* 5: 212-213, 2013.