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BRIEF REVIEW

Long-Term Athletic Development: Part 2: Barriers to Success and Potential Solutions

AU2

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Abstract

Lloyd, RS, Oliver, JL, Faigenbaum, AD, Howard, R, De Ste Croix, M, Williams, CA, Best, TM, Alvar, BA, Micheli, LJ, Thomas, DP, Hatfield, D, Cronin, JB, and Myer, GD. Long-term athletic development: Part 2: Barriers to success and potential solutions. J Strength Cond Res XX(X): 000–000, 2015—The first installment of this two-part commentary reviewed existing models of long-term athletic development. However, irrespective of the model that is adopted by practitioners, existing structures within competitive youth sports in addition to the prevalence of physical inactivity in a growing number of modern-day youth may serve as potential barriers to the success of any developmental pathway. The second part of this commentary will first highlight common issues that are likely to impede the success of long-term athletic development programs and then propose solutions that will address the negative impact of such issues.

Key Words youth, children, adolescents, resistance training, fitness, long-term athlete development

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Introduction

Although longitudinal data are needed to validate the design of existing pathways of either talent or athletic development, it is generally considered more beneficial to have a progressive system in situ rather than have no structure at all. However, although long-term athletic development programs continue to evolve, a number of contraindicating factors associated with modern-day lifestyles of youth are becoming an increasing cause for concern. Enhancing practitioner's knowledge and understanding of how exercise prescription for youth should align with training age, technical competency, growth, maturation, and development is crucial to the progression of our field (59). However, without addressing current issues facing the development of today's youth, practitioners will likely be working in a compromised environment. Specifically, this article will examine how long-term athletic development programs are negatively impacted by (1) inactive lifestyles of youth, (2) the prevalence of obese and overweight youth, (3) early sport specialization and associated injury risk, (4) high workloads of young athletes, and (5) the limitations of existing education curricula.

Operational Terms

For the purposes of this commentary, the terms youth and young athletes represent both children (generally up to the age of 11 years in girls and 13 years in boys) and adolescents (typically including girls aged 12–18 years and boys aged

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14–18 years). The term athletic development refers to the physical development of youth that encompasses the training of health-, skill-, and performance-related components of fitness. The age-related integration of these components over time is designed to enhance performance, reduce injury risk, and enhance the confidence and competence of all youth. Practitioner denotes an individual responsible for the athletic development of youth and includes: youth sport coaches, sports administrators, strength and conditioning coaches, physical education teachers, athletic trainers, physiotherapists, and other health care providers. Resistance training refers to a specialized method of conditioning, whereby an individual is working against a wide range of resistive loads to enhance health, fitness, and performance (57). Forms of resistance training include the use of body weight, weight machines, free weights (barbells and dumbbells), elastic bands, and medicine balls. The term physical literacy refers to the ability of an individual to use cognitive processes such as anticipation, memory, and decision-making to help move with poise, economy, and confidence in a range of physically demanding environments (131). Fundamental movement skills represent locomotive (running, skipping, and hopping), manipulative (catching, throwing, grasping, and striking), and stabilization (balance, rotation, and antirotation, and bracing) skills (64).

Problem 1: Physical Inactivity

It can be observed from longitudinal data that fitness levels of youth in general have deteriorated over the past 20–30 years (77,10 8,125). Recent evidence now indicates that a large proportion of children and adolescents routinely fail to accumulate recommended physical activity guidelines proposed by leading health authorities (36,42). Of particular concern, researchers have shown that physical activity levels appear to peak at approximately 6 years of age, after which there is a consistent decline into adolescence and adulthood (126). Additionally, increases in the amount of time viewing television or playing video games (11), reductions or the removal of time devoted to recess (2), reduced time during the school day for physical education (9 4), reductions in the number of youth who use active transportation to school (107), poor dietary behaviors (14,21,109), and insufficient levels of sleep (37,69,120) are some other lifestyle factors that contribute to reductions in daily physical activity among youth (86). Failure to address negative trends in lifestyle factors such as insufficient sleep or poor dietary behaviors in youth will undoubtedly reduce or blunt the beneficial effects of exercise and potentially increase the risk of sport- related injury. Additionally, researchers have shown that participating in moderate-to-vigorous physical activity (MVPA) is positively associated with emotional state in adolescents (115). Combined, these factors will limit, delay, or postpone athletic development irrespective of the innate talent of the young athlete. Recognizing that daily physical activity early in life is a critical component of all long-term athletic development models, it is imperative that practitioners responsible for the health and well-being of youth are cognizant of the importance of these contributing lifestyle factors and progressively use targeted programming with appropriate interventions.

Cohen et al. (18) indicated that there has been a recent and sustained decline in the muscular strength levels of chil- dren within the United Kingdom, reporting a 26% decline in arm strength and a 7% drop in handgrip strength between 1998 and 2008. Additionally, 1 in 10 children could not support their own body weight on a wall bar (18). The authors suggested that the decline in strength levels was likely because of reductions in physical activity levels. Data from other countries shows a similar trend of strength def- icits in youth, highlighting declines in both handgrip strength and bent-arm hang performance in Spanish adoles- cents (77) and a decline in the neuromotor fitness of pre- pubescent Dutch children (10 8). Cumulatively, these data indicate that modern-day youth do not possess sufficient levels of muscular strength largely due to physical inactivity. This is an issue that requires immediate attention.

The increased prevalence of deconditioned youth is likely to have a direct impact on the current requirements and future structuring of long-term athletic development programs. Youth require coordinated muscular strength for the successful performance of fundamental movement skills (28,67). It is also established that fundamental movement skill competency is associated with long-term engagement in physical activity (63). Therefore, given the recent decline in both of these fitness parameters, any long-term strategy should prioritize the development of muscle strength and motor skill proficiency during the primary school years. It is imperative that youth engage in training modalities to develop muscular strength and fundamental movement skills in early childhood to maximize their modifiable neuromuscular systems (28,92). These evidence-based guidelines challenge previous athletic development models (8) and counter preconceived concerns surrounding structured resistance training for children.

Potential Solutions to the Problem. Considering the existing levels of inactive youth (36,4 2) and that childhood inactivity typically leads to sedentary lifestyle behaviors in adolescence and early adulthood (20,100,121,123), it is imperative that youth engage regularly in strength-building and skill- enhancing activities at an early age. Researchers have pre- viously stated that because of the neural plasticity associated with preadolescence, early engagement in integrative neuro- muscular training (INT) (which comprises of both health- and skill-related components of fitness) is instrumental in developing long-lasting fundamental movement competency and enhanced physical, psychological, and social develop- ment (8 4). Although it is difficult to identify a definitive age at which to start formalized training, most 7 and 8 year olds are ready for some type of structured training as part of fitness recreation, sports practice, or physical education (31). However, younger children (,7 years of age) should

still be encouraged to engage with less formalized structured and unstructured activities (e.g., introductory gymnastics and playground activities that promote kinesthetic development and physical literacy). Of note, authors of the 2014 international consensus statement on youth resistance training stated that the child should be emotionally mature enough to accept and follow instructions and possess competent levels of balance and postural control (57).

Despite global physical activity guidelines recommending youth accumulate 60 minutes of MVPA per day (13 2), details outlining what should comprise 60 minutes of MVPA are somewhat general. The WHO (13 2) suggested that daily physical activity guidelines for 5–17 year olds should com- prise mainly aerobic exercise; with higher intensity training that "strengthens muscle and bone," being performed 3 times per week. Although these guidelines offer support for youth to engage with physical training, it is noteworthy that a greater emphasis is placed on aerobic exercise in compar- ison with exercise that promotes "muscle and bone strength- ening" or skill-building activities. Conversely, practitioners should acknowledge that developing fundamental move- ment skills and muscular fitness within a well-rounded train- ing program should be the priority for youth, as these physical qualities ultimately provide the foundations for MVPA and help to enhance performance and reduce sport- and physical activity-related injuries. This contention is re-inforced by research that shows children with high aerobic fitness and low muscle strength are at a significantly greater risk of skeletal fracture than youth with higher levels of muscle strength and lower aerobic fitness (17). Additionally, a recent position statement from the American Medical Society for Sports Medicine highlighted that a wealth of research now exists that shows neuromuscular training can reduce injury risk, especially injuries to the lower limb (27). Clinical researchers have indicated that the risk of overuse injury can be reduced in youth populations if children and adolescents engage with appropriately prescribed and well-supervised training programs (75,114). Furthermore, it is purported that training programs inclusive of resistance training that target risk factors associated with injury risk (e.g., muscle imbalances) have the potential to reduce over-use injuries by as much as 50% in youth (75,12 8).

T1 Table 1 summarizes the recommended solutions to reduce the negative impact of physical inactivity on the success of long-term athletic development programs.

Table 1. Recommendations for reducing physical inactivity in youth.

Starting early in life, all boys and girls should be encouraged to accumulate at least 60 min of MVPA daily as part of active transportation, free play, recreation, physical education, recess and sport
The building blocks of MVPA, namely muscular strength and fundamental movement skills, should serve as the foundation for youth development programs
Practitioner's need to value both health and skill-related components of physical fitness to avoid negative trajectories in physical and psychosocial well-being in children and adolescents over time
Participation in physical activity should not begin with sports practice and competition but rather evolve out of general preparatory conditioning

Problem 2: Prevalence of Overweight and Obese Youth

The concept of "underuse" injuries suggests that inactivity and a lack of preparatory conditioning is a likely risk factor for the etiology of a number of sports- and physical activity-related injuries (118). In comparison with normal weight youth, data show that overweight and obese children and adolescents are twice as likely to experience an injury when participating in sports or general physical activity (72). Con- sequently, it is suggested that overweight and obese youth are ill-prepared for the physical demands of sports (57), ultimately placing them at an increased risk of injury (106). Specifically, low fatigue resistance, lack of postural and neu- romuscular control, inadequate strength levels, and reduced motor control development have all been proposed as potential mechanisms that increase injury risk within this population (72). Considering the increased demands of con- trolling an excessively large body mass in response to the unpredictable and dynamic nature of sporting activities, overweight and obese youth should engage in preparatory training, inclusive of both health- and skill-related fitness components before participating in organized sport. A sim- ilar approach should be taken for those youth who are of normal weight but inactive. Of note, normal weight inac- tive youth may appear ready to engage in sport; however, their musculoskeletal systems are likely to require general preparation to meet the demands of sports practice and competition.

Practitioners and parents alike should recognize that participation in sport practices will not necessarily provide enough of a training stimulus to suitably prepare overweight and obese youth for the loadings encountered within sports. Researchers have shown that engagement in organized sports does not guarantee youth attain recommended daily physical activity guidelines (55), nor enable individual needs to be addressed, such as excess body mass, muscle imbalances, dysfunctional movement patterns, and strength and power deficiencies. Similarly, it has been suggested that the risk of acute traumatic injury (e.g., ankle sprain or anterior cruciate ligament injury) is decreased in overweight and obese individuals who participate in age-appropriate preparatory neuromuscular conditioning activities (57,72). Impor- tantly, this risk is reduced to a greater extent when

conditioning activities are introduced to youth at an early age (9 2). Collectively, the data support the premise that a training philosophy based on targeting muscular strength and fundamental movement skills within a well-rounded training program is a suitable approach for obese and over- weight youth, much in the same way training prescription is viewed for normal weight children and adolescents (110). Crucially, to maximize their participation in physical activity into adulthood, obese, and overweight youth should be encouraged to adhere to the hallmarks of existing long- term athletic development theory (58) as an ongoing lifestyle commitment.

Potential Solutions to the Problem. Historically, physical activity interventions aimed at preventing or treating overweight and obese youth (especially children) have focused on aerobic exercise (4,110). However, such training modalities can be problematic in terms of compliance and adherence (110). Conversely, training interventions inclusive of motor skill training, strength and power training, and sprint training have all shown relatively high adherence rates in training interventions ranging from 8 to 52 weeks in duration (71,110,112,113). The increased adherence rates associated with neuromuscular training for obese and overweight youth is not surprising given the heightened imposed demands of handling excess body mass for prolonged periods of weight- bearing exercise, in comparison with their normal weight peers. Exposing overweight and obese youth to aerobic exer- cise (e.g., prolonged periods of running within a physical education class) may actually increase their risk of injury and reduce their self-esteem because of the nature of peer comparison within school-age youth. Researchers have shown that overweight youth experience greater levels of criticism during physical activity (35), and such criticism may limit subsequent engagement in physical activity. Although peer comparison may be a negative process during aerobic exercise, in contrast, resistance training offers overweight and obese youth the opportunity to outperform their peers with respect to absolute strength performance. For example, Deforche et al. (2 4) showed that overweight youth performed better than normal weight youth in activities requiring muscular strength. Although overweight and obese youth carry excess fat mass, they typically possess a large fat- free mass also, thus increasing their potential for absolute strength performance (110). Consequently, overweight and obese youth may be more compliant and enthused to regu- larly participate in integrative neuromuscular-based training programs.

Irrespective of the potential additive benefits of resistance training programs for overweight and obese youth, practitioners must remain sensitive to the potentially heightened concerns that these populations may have about their increased body mass, especially when overweight and obese youth exercise within the same setting as normal weight youth. Consequently, practitioners will likely need to differentiate activities within training sessions (and overall training programs) to help enable all youth to achieve success irrespective of their body mass. This approach will help foster an approach to exercise that encourages self-improvement and positive social interactions.

Table 2 summarizes key guidelines for practitioners to consider when working with overweight or obese youth. T2

Problem 3: Early Sport Specialization

Although the injury risks associated with overweight and obese youth arise from insufficient exposure to sports and physical activity (72), of growing concern for children and adolescents are the injury risks associated with excessive exposure to specific sport(s) (27,46). Early sport specialization refers to the engagement in intensive year-round training within a single sport (27) and likely limits the child's exposure to a breadth of sporting activities. It is acknowledged that certain sports traditionally favor early specialization (i.e., gymnastics or figure skating) because of the relative advantage for a young athlete to perform extreme specialized posturing and rotation of the torso and extremities. However, these young athletes should also be engaged with an integrative strength and conditioning program focused to diversify motor skill development and enhance muscle strength to maximize performance and reduce their relative risk of injury. Unfortunately, an increasing number of sports are focusing on exposing children to high levels of formalized sports training at younger ages, even in sports that are typically classified as late specialization sports (e.g., football and rugby) without supportive training to enhance motor

TABLE 2. Recommendations for practitioners working with overweight or obese youth.

Create age-related and body size-sensitive opportunities for overweight and obese youth to gain competence and confidence in their general physical abilities before they attempt to participate in sports practice and competition
Encourage overweight and obese youth to participate in supervised resistance training activities because this type of conditioning can enhance a range of physical performance measures and indices of health
Overweight and obese youth are more likely to experience personal success during resistance training sessions in comparison with prolonged continuous aerobic training
Develop innovative opportunities for normal weight and overweight/obese youth to exercise together in a supportive environment in which all participants have an opportunity to experience success and feel good about their accomplishments in a socially supportive environment

skill competency. Researchers have indicated that youth who do specialize early in a sport are at an increased risk of overtraining, overuse injury, and burnout (i.e., stress-induced withdrawal) (1,26,45). Talented youth who are selected for a sporting team during late adolescence but have not engaged in age-appropriate conditioning during their childhood years are more likely to present with poor funda- mental movement skills. For example, Iga et al. (48) showed that the muscle-loading patterns associated with youth soc- cer can lead to alterations in functional hamstrings to quad- riceps strength ratios about the knee, and that untrained young soccer players presented with greater quadriceps dominance than those who have participated in formalized resistance training. Recently, researchers have proposed that for those athletes who have specialized in a single sport at an early age, physical training should concentrate on enhancing generic movement skills and addressing muscle weakness or imbalances (5 9), instead of being exposed to sport-specific performance-driven training. Providing progressive and mul- tifaceted training opportunities for such athletes to develop more fundamental movement skills may overcome the pro-pensity for early specializing athletes to be at increased risk for a sports-related injury, illness, or burnout (45,92).

It is accepted that not all acute injuries are unavoidable in sport; however, practitioners should be cognizant of risk factors that may predispose youth to overuse injuries. Overuse injuries are defined as an injury caused by repetitive submaximal loading of the musculoskeletal system with inadequate recovery time for subsequent adaptation (27,114). It is suggested that the proportion of acute versus overuse injuries in youth is approximately 50:50; however, it is feared that the number of overuse injuries is rising (12). Conditions such as patellofemoral pain (65,87), Osgood– Schlatter disease (41), calcaneal apophysitis (96), little league elbow (5 2) and little league shoulder (114), spondylolysis (53), and osteochondritis dissecans (101) are all common overuse injuries seen in children and adolescents subject to repetitive sports training. As youth engage earlier in formal- ized sport and specialize in sport(s) at younger ages, they may be at increased risk of experiencing overuse injury (45). Of concern, is researchers have shown that the cycle of reduced activity after an acute injury can initiate overweight and obesity markers in youth (85).

Irrespective of whether long-term modeling is focused on developing talent or athleticism, existing literature is unequivocal that experiencing a range of activities during childhood is an important component of youth development (8,22,40,58). From a talent development perspective, researchers have shown that expert decision-making processes can be enhanced when young athletes are exposed to a breadth and depth of sporting experiences (7). Additionally, it was suggested that exposure to a variety of activities where generic pattern recognition, hand-eye coordination, and decision-making skills can be developed, will ultimately avoid the need for early specialization (7). This is exemplified from the talent development of a young team sport athlete (e.g., soccer player). Although soccer may be the primary sport that the child participates in, they are likely to develop perceptual and decision-making skills such as visual scanning, anticipation, and movement pattern recognition from participating in similar invasion-based sports (e.g., basketball or rugby). Researchers have also shown that a diversification approach to sampling many different sports during childhood is optimal for the development of gross motor coordination (38) and subsequent athletic performance later in life (56,76). Such research refutes the misnomer of the "10,000-hour rule," which is underpinned by an individual seeking to acquire expertise in a given activity needs to engage in 10,000 hours (or 10 years) of deliberate practice, a theory that has been adopted by previous athletic development models (8). Conversely, the research of Moesch et al. (76) and Fransen et al. (38) shows that accumulating 10,000 hours of specific practice does not guarantee success and may not be needed to reach elite performance levels later in life.

From an athletic development perspective, it is important to expose youth to a variety of movement patterns to ensure that a child can competently perform a breadth of movement skills in a range of different activities and environments before specializing in specific movement patterns within a single sport. Children also need to be introduced to a breadth of activities as a high proportion of youth who specialize early will not successfully reach the highest level of elite sport and will therefore require a requisite level of athleticism to support lifelong participation in recreational sport and physical activity. Specifically, a young athlete should be able to repeatedly produce a range of high quality movement capacities (e.g., pushing, pulling, rotating, bracing, jumping and landing, rolling, twisting, hopping, running, and stabilizing) with requisite force production and attenuation before being exposed to the rigors of repetitious sport-specific training.

Potential Solutions to the Problem. Encouraging youth to participate in a variety of sports during their growing years can help them develop more diverse motor skills (82). Sports specialization in youth may underlie reduced diversity in motor skill proficiency as young athletes focus on sport-specific skills, while ignoring motor skills developed through a diversified participation portfolio (38). Although speculative, if sports specialization occurs too early in children and if young athletes continue to progress their level of competition, their opportunities for participation in "fun"-focused age-related physical activities are likely to be limited, which further stifles diversity in motor skills and limits current and long-term physical activity and health (79). Consequently, comprehensive motor skill development will be stifled, which can also increase risk of future injury and potentially reduce opportunities to achieve optimal sport performance (45,79).

Children who do participate in specialized sport activities more than 16 hours a week of intense sport-specific focused

training should be closely monitored for indicators of burnout, overuse injury, or potential decrements in performance from overtraining (8 2). In addition, with the compet- itive demands typically higher for athletes specialized in a single sport, intrinsic risk factors of acute injury that are higher during competition compared with training should be monitored during accumulated games, matches, meets, or tournaments (47,8 2). Specialized athletes involved in intense competition should be allowed for sufficient recovery time between repeated bouts of same day (10,4 9). Before pro- longed competitions, athletes can also benefit from limiting intense training 48 hours before competition (66). Continued research is needed to better delineate the threshold compe- tition volume relative to the emergence of risk factors asso- ciated with overscheduling to better establish formal guidelines to optimize safe youth sport performance (8 2).

Based on the current evidence, we encourage youth to engage in preparatory INT before the initiation of competitive sport participation. Integrative neuromuscular training includes general (e.g., strength-building exercises) and specific (e.g., exercises targeted to address motor control deficits) conditioning activities that are designed to enhance both health- and skill-related related fitness (13,8 4). In terms of physical conditioning, youth sport practice and games may not enable the young athlete to accumulate the recom- mended amount of moderate-to-vigorous physical activity, as a large proportion of time in practice (and even compe- tition) can be spent in sedentary or low-intensity physical activities (4 3,55). A young athlete's participation in sport should evolve out of preparatory conditioning and instruc- tional practice sessions that address individual deficits and prepare their motor systems for the demands of practice and competition (57,8 0). Properly designed INT implemented in preseason and off-season periods can be especially beneficial to athletes who have specialized in sports and may not have had adequate exposure to developmental motor skill activi- ties (8 3). Integrative neuromuscular training provides sup- portive conditioning that can reduce injury risk and enhance performance in all athletes (29,34,82,88–90).

In athletes, it would seem that success at young ages does not predict long-term success, and in some cases, early sport specialization may limit the potential to achieve elite status (82). These data provide support to the concept of early sport diversification and recognizes that while deliberate play and practice and formalized sports training is certainly necessary for success in sports, it is not likely sufficient to achieve maximum performance with reduced injury risk without integration of appropriate long-term athletic training programs (82).

T3 Table 3 summarizes key recommendations to reduce the negative impact of early sport specialization.

TABLE 3. Recommendations for practitioners to reduce the risks of early sport specialization.*

Children should be encouraged to participate in a variety of sports during their growing years to influence the development of diverse motor skills
Practitioners should not subscribe to the notion that children and adolescents must accumulate 10,000 h of deliberate practice to achieve sporting expertise
Children who participate in excess of 16 h of specialized sports activities per week should be closely monitored for indicators of burnout, overuse injury, or potential decrements in performance through overtraining
Although all youth should be involved in preparatory INT before the initiation of competitive sport participation, practitioners should ensure that INT is sensibly integrated into an annual plan that also includes periods of reduced sport-specific training to enhance diverse motor skill development and reduce injury risk factors

*INT = integrative neuromuscular training.

Problem 4: Training Workloads of Youth

For the welfare and well-being of youth, long-term athletic development pathways must be administered and monitored carefully by practitioners responsible for the overall development of the child or adolescent. Without regular communication between practitioners, youth may be at risk for excessive training workloads, contraindicating training methods, insufficient rest and recovery, and additional nontraining stressors. Practitioners should also be aware that although children will often recover more quickly than adults from exercise (especially high-intensity exercise) (105) because of their underlying physiology, the effects of accumulated fatigue on neuromuscular control and function after repeated exposure to exercise in youth remains unclear. Combined, these factors can theoretically lead to excessive workload accumulation and youth experiencing nonfunctional overreaching (6), overtraining syndrome (74), or burnout (61).

Data on youth from the United Kingdom have shown that a relatively high proportion of young athletes have reported experiencing overtraining or nonfunctional overreaching (68). Specifically, 29% of 376 young athletes competing at club to international level from 19 different sports reported experiencing overtraining or nonfunctional overreaching at least once (68). Although Matos et al. (68) indicated that overtraining or nonfunctional overreaching were not solely a result of physical training load, it is likely that a long-term development plan that fails to allow sufficient time for recovery, adaptation, and natural growth processes will increase the likelihood of negative health outcomes for youth (23). When considering the overall workload of the child or adolescent, it is imperative that practitioners value the quality of practice and competition, as opposed to the quantity of training or competition time.

Researchers have shown that parental or coach-led pressure can positively or negatively influence youth (9 9).

Such external pressure to perform in multiple competitions or to train or play when injured to make selection for higher level competitions (i.e., national team rosters or securing professional contracts) can also contribute to the risk of intolerable workloads. Consequently, balancing exposure between competitive events and time dedicated towards physical preparation must be an integral component of any long-term athletic development model.

Possible Solutions to the Problem. The objective of the strength and conditioning coach is to carefully manipulate training loads to achieve long-term adaptations in physical performance. Although practitioners will intuitively adopt their preferred philosophy of periodization (e.g., progressive cycling of various aspects of training), it is generally accepted that planning sequential blocks of training is crucial to elicit the greatest adaptive response. Recently, Haff (44) suggested that for young children entering a long-term athletic development model, the majority of their time engaged within the system should be devoted to general preparatory training and the development of fundamental movement skills. However, as the child moves through the long-term athletic development pathway, a greater emphasis should be placed on competition, so that by the time they reach adulthood (approximately 20 years of age), they will spend 25–35% of their time in training and 65–75% of their time in competition (44). Although these ratios are estimations and do not account for individual differences, the notion of prioritizing general preparatory training and developmental practices during the early stages of childhood is essential. Such an approach will hopefully avoid excessive competitive workloads and negative experiences, which may ultimately lead to premature disengagement from the sport during early adolescence (98). Such an approach should also help ensure the holistic development of youth (97). Interestingly, Matos et al. (68) reported that level of competition was significantly correlated with the incidence of nonfunctional overreaching or overtraining; and therefore, practitioners working with youth must ensure that long-term athletic development is driven by process (athlete-centered) as opposed to outcomes (results-oriented), especially at the younger ages of competition.

The need for a comprehensive approach that is considerate of all demands to long-term athletic development is emphasized for youth who participate in multiple sports. The design of training programs for single-sport athletes will typically include an appropriate phase of physical preparation before the onset of a competitive phase. However, for youth who participate in multiple sports, competitive seasons may run synonymously (i.e., 2 winter sports) or overlap (e.g., a fall, winter, and spring sport). Irrespective of the arrangement of the seasons, practitioners must avoid the temptation of solely focusing on the loading stimulus during training phases and ensure that adequate transition and preparation phases exist within the overall long-term athletic development plan. Enforced transition/preparation phases from sport-specific training are also essential to ensure that the child has sufficient time to rest and recover and to enable normal growth and maturation processes to occur. These phases are also important to safeguard against the negative effects of accumulated fatigue and potential risks of overuse injury. An example of this is apparent in recent recommendations, whereby young baseball pitchers are encouraged to pitch for no more than 8 months within a 12-month time frame to reduce the risk of overuse injury in the shoulder (3). General preparation should also be viewed as an opportunity to regain, or improve on, precompetition levels of fitness that would typically have plateaued or decreased as a result of the demands of the competitive season. For example, during an enforced transition/preparation phase, a practitioner may need to rectify muscle imbalances or decrements in motor skill proficiency that have developed through exposure to competition and reduced opportunities for preparatory con- ditioning. Youth who specialize in a single sport should be encouraged even more to participate in planned periods of enforced preparation to allow exposure to isolated and focused INT, to enhance diverse motor skill development, and reduce injury risk factors (8 2). Such an approach requires a high degree of cohesion between practitioners of different sports/teams, which might be challenging. However, for the long-term welfare and well-being of the child or adolescent adequate preparation time must be viewed as a critical component of any athletic development model.

Several prominent international organizations have recommended that the training of youth athletes should be monitored to avoid the negative consequences of excessive training (1,27,81). Whether these recommendations are being implemented is unknown, but the continued reporting of consistent levels of staleness, burnout, and overtraining in youth sports suggest that more needs to be done to protect youth athletes (50,68,104). Part of the problem is the difficulty of identifying initial symptoms of overtraining in youths. Prolonged impairments in performance are a defining characteristic of overtraining in adults (73). In youth growth, maturation and development may obscure the ability to identify decrements in performance caused by overtraining. Performance decrements lasting months or longer may be caused by a naturally occurring period of adolescent awkwardness, as has been noted in youth soccer players (102). Conversely, overtraining may cause impaired responsiveness to training but with natural growth and maturation processes still allowing some level of improvement or maintenance of performance, masking the negative consequences of overtraining. Supporting the difficulty of identifying physical symptoms of overtraining the American Medical Society for Sports Medicine (27) have stated that there seems to be more of a psychological component to burnout and attrition in youth sports.

A holistic approach should be adopted to monitoring youth athletes, considering both physical and psychosocial perspectives. In addition to performance decrements, the most prevalent physical symptoms association with nonfunctional

overreaching and overtraining in youth sports include loss of appetite, predisposition to injury, frequent tiredness, inability to cope with training loads, frequent respiratory infections, heavy muscles, and sleep problems (68). Although the most prevalent psychological symptoms include apathy, feeling intimidated by opponents, bad mood, often feeling sad, lack of confidence in the future and in competition (68). Coaches should educate youth athletes and their parents to be aware of such symptoms, build a good rapport with their athletes to help identify potential symptoms, have robust monitoring systems in place to allow early detection of overtraining, and have appropriate strategies to deal with suspected cases of overtraining. As an example of psychological monitoring, the profile of mood state has been widely used to identify overtraining in adult athletes and a condensed, 24-question version, has been validated for use with adolescent populations (124).

Key considerations for practitioners to consider when managing the training workloads of youth are presented in Table 4. T4

Problem 5: Current Physical Education Provision

During childhood, the neuromuscular system is highly "plastic" (33,92) and is amenable to adaptation owing to the peaking of brain maturation rates (6–8 years and 10–12 years) (10 3), synaptic pruning (15), and overall strengthening of the synaptic pathways (16). It has also been established that fundamental movement skill mastery and motor proficiency are positively associated with long-term engagement in physical activity (116,117,133), and that childhood is an opportune time for motor skill development. Research also shows that muscular strength is important for motor skill performance (9,19,32,60,122,127), and that children can make worthwhile improvements in muscular strength after appropriate training interventions (9). Consequently, because of the neural plasticity associated with childhood and the responsiveness to motor skill and resistance training, a strong focus of physical education curricula should be based on developing a breadth and depth of movement skills and requisite levels of muscular strength (5 8).

Notwithstanding the awareness of substandard levels of current health and fitness of modern-day youth, the lack of robust governmental strategies for physical activity within the education sector remains a critical cause for concern (130). Not all modern physical education curricula exclusively involve the enhancement of physical fitness and have become more diverse in terms of subject content and required learning outcomes. For example, within the United Kingdom, primary school in addition to pupils being taught to play competitive sports, learn dance and rhythmic movement patterns, and participate in outdoor and adventurous activities; they must also be taught to develop critical thinking skills and learn to use information technology within the physical education setting (25). Despite modern-day policies leading to an increased demand on physical education teachers, it should be noted that the term "physical education" represents the educating program related to the physique of the human body and should encourage psychomotor learning in a variety of settings that promote health and exercise (5). Therefore, even with such a broad range of curricula requirements to satisfy, physical education programs must retain a central tenet of offering youth the opportunity to engage in meaningful physical activity that enhances both health and skill-related components of physical fitness. Because childhood represents a unique opportunity to take advantage of a highly plastic neuromuscular system, exposure to daily primary school physical education curricula would seem to be a critical time frame in which to develop athleticism, promote psychosocial development, and instill motivation for lifelong engagement in regular physical activity.

Despite the obvious role for the education sector to teach and develop health and skill-related fitness in school-age youth, researchers have shown that current education systems are failing to develop appropriate standards of fitness (77,108,119). For example, an examination of the national curricula for physical education within the United Kingdom shows that there is minimal reference to age-appropriate motor skill development and resistance training for school children, especially for primary school education. Furthermore, in the United Kingdom, it is recognized that primary school teachers are poorly prepared through their

TABLE 4. Recommendations for managing training workloads of youth.

For young children entering sport(s) development pathways, focus should be geared towards preparatory conditioning and fun-based activities, with a reduced focus on competitive fixtures. As children mature and develop towards adulthood, the ratio between training and competition should change to reflect a greater focus on competitive performance
Children who engage with competitive sports should follow a long-term athletic development plan than includes preparatory conditioning and transition mesocycles to facilitate recovery, growth, and to reduce the risk of overuse injury
During preparation and transition mesocycles, practitioners should endeavor to address any physical limitations (e.g., reduced muscle strength and power or decrements in sprint mechanics) or common injury risk factors (e.g., muscle imbalances, inefficient landing mechanics)
The process of monitoring training workloads must be holistic in nature and procedures for identifying overtraining in adults should not necessarily be applied to youth

teacher training programs to teach physical education (51), and it has been suggested that the statutory requirements for physical education have often not been achieved (51). It would seem that limited subject knowledge is often the primary explanation for inadequate standards of physical education teaching in primary schools within the United Kingdom (95).

Similar negative trends are evident within the United States, with more than half of all states permitting school districts to allow students to substitute other activities for their required physical education classes (9 3), and 59% of states allowing required physical education credits to be earned through online computer-based courses (9 4). The inability of existing education curricula to appropriately prepare children for the demands of recreational fitness or sporting activities was reflected in recent data examining the preparedness of college freshmen for the rigors of college-based strength and conditioning (12 9). The researchers showed that current college strength and conditioning coaches believed the areas of athleticism requiring the greatest improvement of college freshmen were lower extremity strength, weightlifting technique, core strength, and overall flexibility (12 9). It is reasonable to suggest that if education sectors possess more highly skilled practitioners in the provision of athletic development, the number of youth entering college-based programs with substandard levels of athleticism could be reduced.

Irrespective of the existing concerns with the provision of physical education curricula, a recognized and certified continued professional development (CPD) pathway does not currently exist for practitioners to enhance their knowledge base and practical skill sets within the field of youth athletic development. Furthermore, it is likely that a number of physical education teachers working within schools (especially primary schools) may not be willing or motivated to actively participate in continued CPD opportunities related to long-term athletic development, which poses a very real problem if existing education curricula are to change to address the current syllabus that is delivered to school-age youth. For example, recently, it has been shown that high school physical education teachers' and youth sport coaches' knowledge and understanding of youth resistance training is deficient and not consistent with the recommended guidelines (39,70). Consequently, it is imperative that physical education teacher training programs provide trainee teachers with the relevant curriculum to ensure that, at least, newly qualified teachers possess up-to-date knowledge and the necessary skill sets to deliver appropriate athletic development curricula to all youth.

Possible Solutions to the Problem. Cumulatively, it would seem that the content of existing education curricula and the knowledge of practitioners responsible for the delivery of such curricula are suboptimal for long-term physical development in youth. Despite the short- and long-term benefits of appropriately prescribed physical development interventions on the health and fitness of youth (29,54,62), it would seem that existing education structures require a dramatic overhaul to enhance their capacity to reverse the cascading effects of physical inactivity and its associated negative health outcomes (3 2,130).

Within existing physical education curricula, what could be viewed as "athletic development" is often termed health-related exercise (HRE) and is typically delivered in discrete units of work across a single school term (95), often by practitioners without the relevant expertise in long-term athletic development. These units of work are then replaced with more traditional units of seasonal sports (e.g., rugby, soccer, or hockey). Adopting such a short-term policy will blunt the continual development of athleticism of youth, will likely enable some form of detraining to ensue, and not facilitate the correction of key injury risk factors (e.g., poor landing mechanics or lack of postural stability). Researchers have shown that significant improvements in physical fitness can be achieved from approximately 15 minutes of INT twice weekly (30,2 9). Therefore, some form of targeted athletic development training should be creatively incorporated into all physical education classes (e.g., dynamic warm-up activities) and not just limited to independent blocks of HRE teaching.

The development of athletic potential in school-age youth should be viewed as a long-term process. To adopt some form of periodization to the school physical education system, practitioners should view the school career of youth as a sequence of multiyear plans: (1) primary school years and (2) years spent in secondary education. By integrating a long-term periodized approach within the school system, practitioners can structure sequential annual curricula to progressively build on the athletic potential of all youth. Within each school year, practitioners can then design each term to serve as a structured mesocycle (typically 4–8 weeks), with each teaching week representing a structured microcycle (5–7 days). Although such an approach may initially seem complex and unrealistic, using this type of periodized approach to school-based physical education should offset the chances of exposing youth to isolated blocks of HRE that fails to produce long-term gains above and beyond that of growth and maturation.

Of interest to the practitioner is how philosophies from athletic development modeling (5 8) can be integrated within school-based physical education. Initially, practitioners working within a school system should ensure that children are exposed to varied practices that focus on developing a broad range of athletic motor skill competencies (AMSC (78); Figure 1) and appropriate levels of muscle strength. F1
Such an approach is illustrated within the Composite Youth Development (CYD) model presented in part 1 of this commentary. Within the primary education sector, such practice should be delivered and developed through exploratory activities that stimulate creativity in the child, which, in turn,

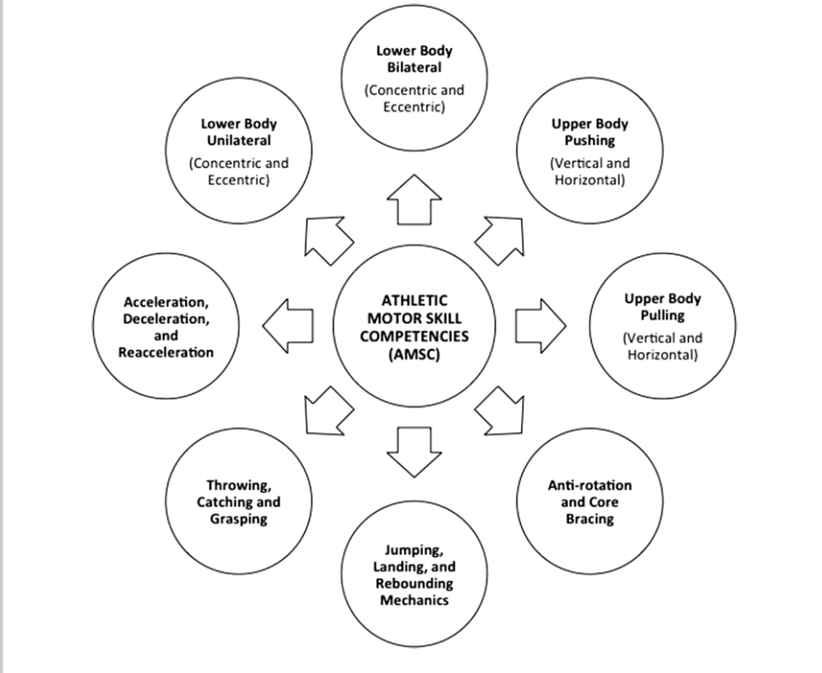

Figure 1. Athletic motor skill competencies (reprinted from Moody et al. (78)). Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

increases enjoyment and motivation. Teachers should avoid relying purely on sport-specific skill development or low-intensity and prolonged aerobic exercise. Additionally, primary physical education should be viewed as an opportunity to teach motor skills that can facilitate more advanced training modes at later stages of development. For example, a teacher should attempt to develop fundamental movement patterns and body weight management ability in young children (e.g., through the use of basic gymnastic type activities) that will act as the foundations for more complex activities (e.g., weightlifting exercises, advanced plyometrics and high velocity, speed, and agility activities). Within the primary school sector where physical education budgets may be limited, practitioners working with youth should realize that expensive equipment is not necessarily required to develop competent motor skill proficiency and primal levels of muscle strength in young children. For example, there are many different forms of resistance that can be used as on overload stimulus to develop muscle strength (e.g., body weight, manual resistance, elastic bands, medicine balls), all of which have proven successful in training interventions in youth (57).

Table 5 provides recommendations for practitioners to consider when working within existing educational systems. T5

TABLE 5. Recommendations for practitioners working within educational systems.

Children should receive targeted integrative neuromuscular training wherever possible within each lesson
"Athletic development" should not be constrained to aspiring young athletes or independent blocks of health-related exercise for a single school term
Wherever possible, schools should adopt a long-term periodized approach to physical education to ensure that youth have the best opportunity to make continued worthwhile changes in physical fitness
The primary school years offer a unique opportunity to develop fundamental motor skills, enhance muscular strength, and improve physical literacy. This should be recognized within primary school curricula, whereby youth should be provided with regular opportunities to develop such qualities within a creative and supportive learning environment

NEED FOR AN INTERNATIONALLY RECOGNIZED YOUTH TRAINING CERTIFICATION

Irrespective of which model is adopted by practitioners, the success of any youth training plan is largely based on the suitability of the program design and the pedagogical skills of the practitioner(s) responsible for its delivery (33,84). Although existing models have undoubtedly furthered the cause of youth training, the depth of understanding of growth and maturation influences on physical performance and how these influence program design remains highly varied among practitioners. Consequently, an internationally recognized youth training certification should be developed and endorsed by professional organizations to help ensure the provision of safe and effective exercise prescriptions for children and adolescents. Importantly, such a certification process would require a practitioner to be assessed for knowledge and understanding of key concepts surrounding pediatric exercise science, the ability to design, coach and

modify developmentally appropriate training programs, and pedagogical skills to ensure that scientific principles can be translated into practice in a child-focused approach. Such a certification process should become accepted practice, not just within sporting administrations but also in the education and health care sectors, especially in light of recent trends in MVPA and the increasing prevalence of sport- and physical activity-related injuries in youth. The concept of an internationally recognized certification is particularly important given the existing knowledge and awareness of current guidelines for youth-specific exercise prescription within the sport, education, and health care systems (32,39,111). Irrespective of whether practitioners are working with youth in competitive sports, recreational activity, daily physical education classes or organized health-based interventions, an internationally recognized certification is deemed as an important developmental step to ensure that philosophies and practices of long-term athletic development are geared towards ensuring the holistic development of all youth.

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