TITLE

Practical Strategies for Integrating Strength and Conditioning into Early Specialization Sports

ARTICLE TYPE:

Narrative review

ABSTRACT

Early sport specialization involves physically immature children participating in intensive year-round training and or competition for a single sport at the exclusion of other sports. Lack of sport exposure and diversification during developmental years may underlie increased risk of overuse injuries, blunting of motor skill development, psycho-social issues, overtraining syndrome, burnout, and potential drop out from sport. With increasing numbers of youth choosing, or being encouraged, to specialize at an early age, we aim to provide evidence-based recommendations for the integration of strength and conditioning into the development programs of young athletes who participate in sports with a culture of early specialization. In addition to principles of programming, strategies are provided relative to monitoring of growth, maturation, and training load to illustrate the potential complexities of attempting to optimize long-term athletic development in early specializing athletes.

KEY WORDS

Specialization, Youth, Training, Long-term athletic development

INTRODUCTION

Early sport specialization is characterised as intensive year-round (> 8 months per year) training and or competition, involving participation in a single sport that typically begins in the pre-pubertal years (34). Early specializing young athletes can be exposed to intensive training schedules (e.g. high volumes and frequencies), with chronic exposure to the same sporting-skills that may limit diversified skill acquisition and reduce long-term participation in sport (34). Notably, these athletes often accumulate weekly training hours which surpass the recommendations of not exceeding the child's chronological age in years (6, 76). Early specializing sports are typically individual in nature and include: gymnastics, figure skating, dance, tennis, and swimming (43, 65, 76). However, the trajectory of youth from other sports choosing to specialize early is growing (6) and overall rates of specialization and the exclusion of multi-sport participation in the developmental years are at an all-time high (62). In the United States, one study with a sample of 1190 young athletes reported ~30% were highly specialized (29).

In certain *early entry* sports, where peak elite performance tends to occur at a younger age (e.g. women's gymnastics, figure skating), early specialization approaches are more accepted with a view to that it is needed to increase the likelihood of success in the sport (34). *Middle-entry* (e.g. tennis) and *late-entry* (e.g. endurance running) sports represent the majority of sports and typically involve peak elite performances at an older age and specialization during middle adolescence and late adolescence or full maturity, respectively (36, 62). However, there is emergent consensus amongst researchers and practitioners opposing an early specialization approach, owing to the associated potential negative effects on children and adolescents' physical and psycho-social well-being (6, 34, 37, 43, 59). Some evidence suggests that young athletes may be at greater risk of developing overuse type injuries (62), experiencing overtraining or burnout syndrome (13), presenting with ‘blunted’ motor skill development (13), and prematurely withdrawing from their sport (34, 37). However, recently some authors have emphasised the need for a more in-depth evaluation of the mechanisms driving these potential negative effects, as well as determining any positive effects (e.g. competence and skill acquisition) of early specialization to improve the overall delivery of youth sports (1). Early adolescence has been recommended as the earliest stage of development at which young athletes involved in early entry sports, should specialize (30, 62). Additionally, authors of position statements have suggested that those involved in sport, should revisit, and reset competitive expectations for young athletes to discourage early specialization (34). For example, greater impact could be achieved if National Governing Bodies share this vision and embed information about the risks of early specialization into their coaching education pathways.

Young athletes typically adopt such an approach with very little chance of reaching the elite levels of sport, notwithstanding the potential physical and psychosocial risks associated with early specialization. While sport offers multiple benefits to children, data indicate that less than 1% of high-school athletes reach the professional level of sports (6, 63). It is important for children to challenge themselves, to be passionate about their sports, and to pursue their sporting dreams; however, key stakeholders responsible for their development should be realistic about the sporting trajectories of any young athlete. Furthermore, there is no guarantee that specializing early in a particular sport will result in success at an elite-level, and research has shown specializing later could be more advantageous (54). Moesch et al. (54) investigated group differences between elite and near-elite young athletes from sports measured in centimetres, grams, or seconds. The authors indicated that elite athletes specialized at a later age and trained less during childhood, but then started to intensify their training regimes during late adolescence, resulting in a higher number of accumulated training hours compared to near-elite athletes (54). One retrospective study in Division 1 collegiate athletes from 17 different sports reported that more athletes participated in multiple sports than a single sport and concluded that specialization was not a requirement to reach elite levels (51). However, the average age of specialization and percentage of athletes who specialized varied considerably across the different sports. For example, ~73% gymnasts and ~54% figure skaters specialized at the youngest age (age range 8-10 years), whilst ~86% hockey players specialized on average at ~12.5 years old (51). Further, recent reviews of literature have explored the impact of early specialization on career and task-specific athletic performance and concluded that sport specialization was not a prerequisite for success at more elite levels (33, 75).

It is our opinion, and those proponents of existing long-term athletic development (LTAD) models and position statements, that young athletes should refrain from specializing in a single sport until later in adolescence (34, 37, 84). While a sea change is required in youth sports to arrest the move towards early specialization, many youth strength and conditioning practitioners will inevitably find themselves working with athletes who specialize early. It is important for practitioners working in these circumstances to have an evidence-informed approach to strength and conditioning provision. Children that specialize from an early age will be entering a sporting system prior to the onset of puberty (e.g. gymnastics); therefore, they will experience growth (e.g. increases in size, stature and mass) and maturation (e.g. skeletal, sexual and somatic maturity) processes (18) while also training for, and competing in, their chosen sport.

Young athletes will experience natural fluctuations in physical fitness (39, 52, 69, 80) and injury risk factors (28, 61, 66, 67) at certain stages of maturity, and the manner in which these developmental adaptations interact with training load is complex and may be heightened in single-sport athletes (11, 49, 64, 74). Consequently, having an awareness of how growth, maturation, and training interact, and an understanding of the unique demands of implementing strength and conditioning programs for early specializing athletes, is important. Similarly, practitioners may work with these athletes at the beginning of their LTAD journey and hopefully oversee their non-linear development towards young adulthood. Therefore, the purpose of this review is *firstly*, to examine how growth and maturation data can be used to inform programming with early specializing athletes; *secondly*, to provide practitioners with advice and recommendations on how to integrate strength and conditioning with a LTAD approach into the programs of early specialization athletes; and *thirdly*, to discuss strategies of monitoring training loads for early specializing athletes.

CONSIDERATIONS WHEN WORKING WITH EARLY SPECIALIZING ATHLETES

Use of growth and maturation data

It is important to recognize that while athletes starting out in early specialization sports will be typically in the prepubertal stage of development, differences in maturation may already exist as the skeleton continually develops throughout childhood and adolescence (18). Consequently, choosing the most appropriate method of assessing maturity status in early specializing athletes is important (42). Owing to the limitations and restrictions associated with skeletal age verification or sexual age estimation, it has been recommended that practitioners rely on somatic assessments to estimate biological maturity (42). Methods by Mirwald et al. (53) and Moore et al. (58) which predict maturity offset, may not be valid in prepubertal athletes if they are not approaching peak height velocity (PHV) (47, 48). Therefore, the Khamis and Roche method (32) of estimating percent of predicted adult height (%PAH) attained is likely to be the most appropriate method of identifying prepubertal athletes' stage of maturity and has been used within the literature to group athletes into ‘bands’ (10, 45). For example, Cumming et al. (10) indicated how %PAH can be used to bio-band young athletes using the maturity offset method (i.e. < -1, pre-PHV; -1 to +1, circa-PHV; and > +1, post-PHV) or bands for %PAH attained (i.e. <85%, pre-pubertal; 85%-90%, early-pubertal; 90%-95%, mid-pubertal; and >95%, late-pubertal). It should be noted that when using the methods developed by Khamis and Roche (32) to predict %PAH attained, where possible parental height should be measured directly to increase the accuracy of predictions.

The on-going collection of anthropometric data (e.g. body mass, standing, and sitting height) every 3-months to allow growth rates to be calculated is also recommended (80) in early specializing athletes and all young athletes. If longitudinal growth rate data are obtained, PHV and peak weight velocity (PWV) can be identified in early specializing athletes around the time of the adolescent growth spurt. PWV tends to occurs after PHV and notably, boys and girls reach PWV within different periods of time (i.e. boys = approximately six months, girls = few months up to a year) (44). Coaches can subsequently use growth and maturation data to estimate when early specializing athletes are experiencing rapid periods of growth or are approaching the adolescent growth spurt, which may inform the training strategies detailed below (10, 45).

It should be noted that when early specializing athletes approach the pubertal growth spurt, injury risk may increase concomitantly (61, 67, 73, 74) and individuals might experience a plateau or decrement in some aspects of performance (44, 46, 56). However, PHV and PWV do not necessarily cause injury, rather, the periods of rapid growth are likely to increase the relative risk of injury and specifically the proliferation of risk factors in early specializing athletes (e.g. significantly greater knee abduction angles and moments during landing tasks compared to the multisport athletes) (11, 12). Importantly, maturity data should be used by practitioners to help early specializing athletes and technical coaches to understand potential changes in performance or function and provide objective data that can be considered as part of interdisciplinary conversations regarding optimizing programs to promote improvements in performance. For example, a young tennis player experiencing rapid growth could find performing shots and skills temporarily more difficult, as a result of increases in limb lengths and the height of their centre of mass, making co-ordination, and dynamic joint stabilization more challenging. During this unique stage of development, coaches may need to consider modifying the athlete's training emphasis (e.g. revisit athletic motor skill competencies (AMSC *figure 1*) and increase relative muscular strength), incorporate targeted injury prevention exercises, and monitor training loads and volumes closely (45, 62, 74), as opposed to removing athletes from the program.

Insert figure 1 near here

Engaging with key personnel

Overuse injuries in early specializing athletes are likely to be more avoidable than acute type injuries, with estimates of ~50% deemed preventable in youth with appropriate training and management (82). Fostering a collective approach to training with technical coaches and parents of early specializing athletes can be challenging. The perceived belief that high amounts of sports-specific training early in childhood will lead to an increased likelihood of sporting success may exist amongst technical coaches and parents (62), whereas the associated increase risk of injury might be less well understood (2, 3). In a recent survey conducted with parents, over 80% had no knowledge of sport volume recommendations regarding hours per week (~84%), months per year (~82%), and only ~43% thought that year-round sport participation may increase the risk of overuse-type injury (3). Early specializing athletes might also be encouraged to practice at home, which results in the accumulation of even higher and uncontrolled overall workloads. Children are advised not to participate in more hours of sport per week than their chronological age, or greater than a maximum of 16 hours per week (6, 34, 62). However, these training volumes are often exceeded in sports such as gymnastics, baseball, tennis, and swimming (50, 76), and year-round training and overscheduling of competitions exists in early specialization sports (6, 29). In an attempt to better manage overall workload stress, it is recommended that strength and conditioning should replace part of the weekly training volumes of those early specializing athletes with high weekly training volumes, rather than merely being an addition to the program. However, it is acknowledged that this approach will require effective collaboration and a shared vision amongst the athlete(s), technical coaches and parents.

Developing meaningful and respectful relationships with technical coaches and parents in addition to the young athletes themselves is imperative to build a truly holistic athlete-centred program (24, 26). In doing so, it is easier to explain and justify the need for a long-term commitment to strength and conditioning programs. Non-scientific language should be used and engaging resources (e.g. infographics) could enhance the understanding of coaches, parents, and the athletes themselves of why strength and conditioning is an important element of the program (see *figure 2*). Anecdotally, inviting technical coaches, parents, and early specializing athletes to 'welcome meetings' at the start of a new competitive year can be extremely useful. Such events enable practitioners to highlight the benefits of strength conditioning, provide insights into what is involved and dispel myths around particular modes of training (e.g. resistance training with young athletes). Having open conversations with all parties and providing them with opportunities to ask questions about the training program or testing reports is strongly encouraged (24). This would be particularly useful when setting goals to make sure the athlete's expectations are realistic and to ensure that they feel involved in the process to enhance autonomy (24). Further, if testing reports are produced, they must be easily understood and presented in an engaging way (e.g. use of visual and audio methods). *Figure 3* shows an example report for a young gymnast (27).

Insert figure 2 near here

Insert figure 3 near here

Implementing LTAD-centred strength and conditioning programs

Through high volume periods of sport-specific training, some early specialization athletes may display advanced or even adult-level technical skills at young ages (e.g. golfers who display very advanced technical skills as a result of deliberate practice from a young age) (43). However, the perceived need for these athletes to reach advanced standards ahead of their time is short-sighted and may have negative connotations (43). Therefore, a long-term approach to the physical development of early specializing athletes is needed, with health, and wellbeing a central priority (34, 62). Recommendations for practitioners working with early specialization athletes looking to adopt this approach are shown in *Table 1*. Practitioners (and technical coaches) must remember that early specializing athletes are not 'miniature adults' and therefore, the training strategies and structure of sessions must be developmentally appropriate (15, 20, 81). For example, elements of non-structured forms of training should be included in all training sessions regardless of training age or stage of development, to encourage movement creativity, and exploration (e.g. obstacle courses, playground games) (68).

Program design: enhancing athleticism

Another priority for those working with early specialization athletes should be to promote LTAD and foster talent development in a holistic manner (64). Effective motor skill execution is underpinned by correct fundament movement patterns, cognitive processing, and force production and absorption (9, 68). Therefore, muscular strength and a broad range of AMSC (see *figure 1*) should be developed synergistically to enhance early specialization athletes' overall levels of athleticism (68). Exposing these athletes to a combination of general and specific strength and conditioning activities that develop AMSC and enhance health and skill-related components of fitness is recommended (16, 60, 62). Practitioners should target the development of movements that are not inherent in the sports of early specializing athletes in order to develop well-rounded athletes with a broad foundation of athleticism (55, 62). As heightened levels of neuroplasticity are apparent during the prepubertal stage of development (4), it would seem prudent to exposure these athletes to neuromuscular training early, prior to growth-related disturbances which may occur with adolescence (62, 72). A training dosage of two sessions of neuromuscular training per week has been shown to enhance measures of isometric force-time characteristics (14), motor skills (e.g. squat jump height (14) and standing long jump distance) (16), and movement competency (57) beyond those in age-matched controls, in pre-pubertal children. Cumulatively, these studies show the potential benefits appropriate strength and conditioning programs can offer pre-pubertal children, with relatively low doses of training exposure. Practitioners should refer to work by Radnor et al. (68) for further guidance on how to develop AMSC in youth using developmentally appropriate and engaging training strategies.

Owing to the high volumes and frequency of sports-specific training sessions in early specialization sports, strength and conditioning practitioners may often be required to deliver sessions 'on field' at sports training locations (e.g. tennis court, gymnastics centre). The equipment, time, and space available for training is likely to depend upon the nature of the sport, competitive level, and culture of the club. Practitioners working within more challenging training situations must therefore be flexible and consider the most effective and efficient training strategies available to elicit the targeted adaptation. The sequencing of the strength and conditioning provision and the early specializing athlete's sport-specific training should be considered. For example, a 5-week neuromuscular training program including plyometrics, acceleration, deceleration, and COD drills using minimal equipment (medicine balls, boxes etc), implemented before and after a tennis session were evaluated between pre-practice and post practice in high-level prepubertal male tennis players (22). From the data it was concluded the program that took place prior to tennis-specific sessions was more effective in improving tennis performance–related factors (e.g., sprint, jumping performance, and serve velocity) than the program that took place after tennis-specific sessions (22). These findings highlighted the potential benefits of implementing strength and conditioning programs prior to sports-specific sessions to optimize the training responses, when levels of neuromuscular fatigue are lower. However, in some instances there might be a rationale for arranging strength and conditioning sessions after technical session to challenge movement control in a fatigued state; therefore, practitioners must be clear on what the aims of the training sessions are.

Insert table 1 near here

Another challenge for practitioners is to provide an effective training stimulus variation that is different to what early specializing athletes typically experience during their sport-specific skill training that will induce adaptations above those that they will acquire from their high volumes of technical training and competition (55). This is likely to be more relevant in early specialization sports that involve high amounts of sport-specific physical preparation. For example, combined strength and plyometric training significantly increased elite pre-pubertal gymnasts' drop jump performance, with the authors recommending a reduction in the time spent on habitual repetitive routines to allow time for an alternative and more targeted strength and power training stimuli (50). It should be noted that the nature of early stage strength and conditioning for young athletes will initially focus on the execution of foundational athletic movements (e.g. squatting and hinging) using body weight as a form of resistance; however, to realise ongoing adaptations and as training-age and technical competency increases, higher intensity resistance training will be required to further enhance strength and power qualities (35). Training will need to be progressively overloaded (37) but also considered in light of the early specializing athlete's overall training load. For example, as a young gymnast approaches a competition mesocycle, they will complete more full routines at higher intensities (e.g. landings and dismounts on to mats instead of foam pits, and tumbling on harder surfaces); consequently, practitioners may benefit from reducing the volume and or intensity of high-impact plyometrics during this phase to avoid excessive amounts of high-impact landings which could lead to overuse injuries.

Program design: reducing injury risk

When designing training programs to enhance performance and reduce injury risk, conducting a thorough needs analysis of the sport's demands (physiological and biomechanical) (70) and types of activities the early specializing athlete will be frequently exposed to is important. Coaches should consider injury epidemiology within the sport to identify: common overuse injury sites, areas prone to strength and mobility deficiencies, postural issues, and limb asymmetries (70, 74). Because overuse injuries can be prevalent in early specializing athletes (31, 34, 37, 43, 59), practitioners should adopt a philosophy and implement practice that includes a large movement variability, with the aim of providing exposure to a variety of movement patterns to vary the point of force application and co-ordination demands (37). Further, if growth-related injuries are prevalent in the sport, practitioners should also be aware of the underpinning mechanisms, and the signs and symptoms associated with these injuries.

Should an early specializing athlete display gradual onset of pain, a symptom indicative of overuse injuries (31), medical advice should be sought, and appropriate rehabilitation and management strategies should be integrated into the training program. For example, as lumbar-spine injuries are prevalent in golf players, incorporating anti-rotation exercises to reduce injury risk, and aid in spinal motion control could benefit young golfers (71). It must be stressed that one size will not fit all, as these factors will differ markedly between early specializing athletes from different sports (e.g. differences in high-impact training of gymnasts compared to rowers). For example, young rowers would benefit from training which targets posterior chain strengthening, non-sagittal movement patterns and basic jumping, landing, and rebounding mechanics. Conversely, practitioners working with young gymnasts might limit the amounts of jumping and rebounding activities they incorporate into training, particularly during busy periods of competition. Thus, considering which AMSC the early specializing athletes' sport does not address will be important to reduce injury risk and develop well-rounded athletes (68). Practitioners should refer to Read and colleagues (72) for further guidance on how to implement evidence-based training strategies that can effectively reduce injury risk in youth.

An integrated approach to monitoring workloads for early specializing athletes

Measures of training load are typically categorized as either internal or external (5) and can be used to monitor athletes' responses to training and readiness to train (27). Internal training loads describe the relative biological stressors (physiological and psychological) imposed on an athlete during training or competition and are commonly assessed using: heart rate, blood lactate, oxygen consumption, and rate of perceived exertion (RPE) (5). Whereas external training loads are objective measures of the work that an athlete has completed during training or competition (e.g. total distance covered, number of jumps and throws, volume-loads) (5).

A key role for practitioners working with early specializing athletes is to assist with monitoring of internal and external training loads, as well as utilizing screening tools for indicators of overtraining and burnout (fatigue, reduced performance, illness etc.) (62, 74). Researchers have monitored training loads over 41 weeks in young athletes from various sports and reported intensity during the week prior to injury was significantly higher compared to that of the preceding 4-weeks (49). The influence of training load 'spikes' on injury risk in youth was evaluated in a 2-year study in male youth cricketers monitored acute and chronic workloads of bowling sessions and found that 'spikes' in workloads were associated with an increased injury risk (83). Specifically, an increase in acute- and chronic-workloads of more than two standard deviations, resulted in a 4–5 fold increase in injury risk in the subsequent 4 weeks (83). These type of data can be used to inform the planning of training workloads around different seasons and competition demands to ensure sufficient chronic workloads are maintained, whilst minimizing spikes in workload (83). Indeed, this is likely to be more challenging in certain sports than others, nevertheless with such an approach, acute and chronic training loads could be managed more carefully. Indeed, the organization and monitoring of weekly training loads is a complex process and can be challenging owing to individual fluctuations in overall training loads (e.g. practicing at home, training camps, competitions, school and club training commitments) as well as, large interindividual variances in responses to load (78, 79). However, integrating monitoring processes will allow training loads and recovery bouts to be modified between training sessions to reduce the risks of maladaptive training responses (e.g. overtraining, burnout, overuse injury) (78).

Notwithstanding the range of metrics to quantify workload from different training modes (e.g. volume-loads from resistance training, or distances covered during a conditioning session), one viable method of monitoring athletes' internal response to training across a wide range of training modes is the session-rating of perceived exertion (sRPE) (78). Using this approach with early specializing sports requires the young athletes to state an overall RPE for a given training session which is then multiplied by the session duration. Given the likely young ages of early specializing athletes, anecdotal experience has shown that parents and technical coaches are often needed to assist with the monitoring process and that a period of familiarization is required to ensure children can provide meaningful and more accurate subjective responses using the RPE scale. The use of child versions of sRPE after each session is encouraged and has been validated with resistance training (see *figure 4* for an example sRPE scale used with a gymnastics group) (19) and field-based sessions in youth (77). Valid data can be obtained using online platforms (e.g. web-based questionnaires, spreadsheets) and athletes should be encouraged to report sRPE 30 minutes after training (23), or no longer than 48 hours post-training (21, 78). In young athletes their coaches' intended training load does not always align to the athletes' perceived sRPE load, resulting in a mismatch which could lead to a maladaptive training response (8, 78). Should training load exceed the practitioner or technical coach's intended dose of training, external training variables can be manipulated to achieve the desired internal response in the following session (78).

Insert figure 4 near here

If equipment, human resource and time allows, measures of neuromuscular fatigue can also be collected to assess athletes' responses to training and or readiness to train using various jumping protocols (e.g. reactive strength index from drop jumps) (27). It should be noted that chronic fatigue could be exacerbated in early specialization athletes involved in sports with traditionally high volumes of training, such as gymnastics and ballet. However, utilising monitoring tools with large numbers of athletes and collecting accurate data across multiple coaches (e.g. school, club, national teams) in practice can be very difficult. Crucially, practitioners are encouraged to observe athletes' demeanour prior to, during, and after training for signs of fatigue (e.g. loss of motivation, lethargy, bad moods), and are encouraged to have reciprocal conversations with them regarding their readiness to train (40). Importantly, training should be adapted accordingly (e.g. reduce session intensity) if the athlete presents signs of accumulated fatigue (40).

Practitioners should work closely with technical coaches to develop ways of monitoring the training loads during sport-specific activities and critically, build in periodic de-load recovery weeks to facilitate recovery and growth processes. Further, in early specialization sports that do not typically have an 'off-season' or train all year-round (34, 76), practitioners should work closely with technical coaches to periodise a post-season or competition transition phase. Further, de-load weeks could be co-ordinated to align with inter-semester breaks (17). Educating parents and coaches about the benefits of reducing training loads for of 2-4 weeks during this transition phase or the inclusion of de-load weeks will be essential. Highlighting the need to reduce training stressors to avoid burnout (7, 13) and allowing early specializing athletes adequate time to recover physically (e.g. dissipate cumulative fatigue) and psychologically from previous training or competition phases is strongly recommended (25). For example, following a competitive phase of training, early specializing athletes could benefit from fun-based ‘challenge weeks,’ which include different types of movement challenges (e.g. sports-acrobatic partner balances) and activities that encourage new skill exploration (e.g. athletes create the obstacle courses) (68). The rationale for this is to reduce the volume of sport-specific skills the early specializing athlete is exposed to, with the aim of reducing overuse-injury risk.

The potential psycho-social implications for athletes specializing from an early age are noteworthy (7). Researchers have indicated that numerous stressors are associated with early specialization such as increased anxiety, competition-related stress, poor sleep quality, social isolation, decreased family time, perfectionism, and burnout (6, 7). Therefore, strategies to reduce the risk of early specializing athletes experiencing physical and psycho-social adverse effects should be prioritized (7). For strength and conditioning practitioners working with young athletes, the aim of training sessions should be to incorporate process-oriented goals for motivation purposes. This approach should also help to create a fun, enjoyable, and holistic training environment and optimise buy-in to the program (40). Further, practitioners should encourage early specialization athletes to communicate honestly about how they are feeling and utilize other monitoring tools such as wellness and mood questionnaires (e.g. sleep quality, soreness, fatigue, motivation to train etc.) and training diaries. Together, these data can be used to better understand the demands and stresses on these athletes and potentially change training cultures in early specialization sports. As parents, technical coaches and the athletes themselves are key to establishing consistent data that provide insights into workloads, it is important that data is reported back to all parties in a timely manner to effectively ‘close the loop’ on the information sharing process.

Coaching insights

Given the young nature of early specializing athletes, coaches should be aware that they could be providing the first experience of strength and conditioning for these children. Consequently, providing a positive, beneficial and engaging training experience should be viewed as a crucial part of the strength and conditioning practitioner's role in promoting LTAD (37). Coaches should aim to develop and maintain authentic coach-athlete relationships (40) and create optimal training environments which are fun and engaging for young athletes to thrive in (e.g. increased autonomy, learning new skills, perceiving self-improvement, increasing intrinsic motivation) (26). For example, allowing young athletes to choose between exercises which have similar adaptations (e.g. squatting variations) will increase their sense of autonomy and in-turn improve their intrinsic motivation to complete the program (24). Further, designing training programmes that include opportunities to build self-confidence (e.g. tasks to create success) and increase resilience (e.g. tasks to challenge) are important for young athletes' psychosocial development (81). It is recommended that all early specializing athletes engage in strength and conditioning and that their programs have an early focus on developing movement competency, force production and absorption, and competence in a broad range of AMSC (34, 37, 38, 41, 62).

When structuring the session, aside from the desired targeted adaptations, practitioners need to consider the characteristics of the individuals, and their training experiences and levels of technical competence. Anecdotally, varying the amount of structure during different parts of the same session can be effective. Warm-ups provide an opportune time for less structure, whereby early specializing athletes can explore a variety of movement patterns and challenges (e.g. using obstacle courses, animal shapes and games), develop motor skills, and play games involving movements that the athlete's sport might not address. For example, incorporating games towards the end of the warm-up that involve more chaotic and reactive movement scenarios for a group of young gymnasts will likely provide a novel stimulus compared to the repetitive and consistent nature of gymnastics training. During the main part of the session greater structure and focus could be placed upon improving more specific aspects of performance, while also addressing any aberrant movements that may be associated with heightened injury risk (41). Again, practitioners should aim to include exercises which address ‘gaps’ in an early specializing athlete’s movement portfolio; for example, a tennis player who is very dominant in upper-body anterior, internal rotation movements may benefit from a greater bias of upper body posterior, external rotation exercises.

Further, practitioners should reinforce simple but important aspects of training that promote good long-term training habits for early specializing athletes. This could include: encouraging and supporting team-mates, completing training logs correctly, reporting any concerns or injuries, and tidying up training areas after use. Apportioning 5 to 10 minutes of less structured training using a game, challenge or competition could be a favourable way to end the session. Anecdotally, highlighting the ‘trainer(s) of the day’ at the end of the session based on effort and application (e.g. improved movement quality) as opposed to performance outcomes (e.g. load lifted), tends to be well-received by early specialization athletes with low training experience (40).

SUMMARY

Early specializing athletes are at greater risk of experiencing overuse-type injuries, blunting of motor skill development, burnout syndrome, and psycho-social issues. Therefore, strength and conditioning practitioners working with these athletes have an important role in integrating holistic, LTAD training programs as well as monitoring growth, maturation, training load, and aspects of wellbeing. Where possible, data should be used to inform training strategies and prescription on an individual basis. It is recommended that early specializing athletes engage in strength and conditioning, and specifically target the development of relative strength and a full breadth of athletic motor skill competencies to improve physical fitness and reduce sports-related injury risk. Whilst overall training load must be considered, integrating strength and conditioning training which targets areas of the early specializing athlete’s physical development that their sport does not address is critically important. Coaches should aim to collaborate with technical coaches and parents as well as build authentic relationships with the early specializing athlete to provide developmentally appropriate strength and conditioning programs that are holistic and athlete-centred.

FIGURE CAPTIONS

Figure 1. Athletic Motor Skill Competences (AMSC) (41)

Figure 2. Why early specializing athletes should engage in strength and conditioning

Figure 3. Example progress report for a young gymnast

Figure 4. Example of a child-friendly sRPE scale (19)

TABLE CAPTIONS

Table 1. Recommendations for those working with early-specializing athletes

REFERENCES

1. Baker J, Mosher A, and Fraser-Thomas J. Is it too early to condemn early sport specialisation? *Br J Sports Med* 55: 179-180, 2021.
2. Bell D, Post E, Biese K, Bay C, and Valovich McLeod T. Sport specialization and risk of overuse injuries: A systematic review with meta-analysis. *Pediatrics* 142: 1-8, 2018.
3. Bell D, Post E, Trigsted S, Schaefer D, McGuine T, and Brooks M. Parents' awareness and perceptions of sport specialization and injury prevention recommendations. *Clin J Sport Med* 30: 539-543, 2018.
4. Blagrove R, Bruinvels G, and Read P. Early Sport Specialization and Intensive Training in Adolescent Female Athletes: Risks and Recommendations. *Strength Cond J* 39: 14-23, 2017.
5. Bourdon P, Cardinale M, Murray A, Gastin P, Kellmann M, Varley M, Gabbett T, Coutts A, Burgess D, Gregson W, and Cable N. Monitoring athlete training loads: Consensus statement. *Int J Sports Physiol Perform* 12: S2161-S2170, 2017.
6. Brenner J and Fitness. ACoSMa. Sports specialization and intensive training in young athletes. *Pediatrics* 138: 1-8, 2016.
7. Brenner J, LaBotz M, Sugimoto D, and Stracciolini A. The psychosocial implications of sport specialization in pediatric athletes. *J Athl Train* 54: 1021-1029, 2019.
8. Brink M, Frencken W, Jordet G, and Lemmink K. Coaches' and players' perceptions of training dose: not a perfect match. *Int J Sports Physiol Perform* 9: 497-502, 2014.
9. 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* 19: 123-129, 2016.
10. Cumming S, Lloyd R, Oliver J, Eisennmann J, and RM. M. Bio-banding in sport: Applications to competition, talent identification, and strength and conditioning of youth ahletes. *J Strength Cond* 39: 34-47, 2017.
11. DiCesare C, Montalvo A, Barber Foss K, Thomas S, Ford KR, Hewett T, Jayanthi NA, Stracciolini A, Bell D, and Myer G. Lower extremity biomechanics are altered across maturation in sport-specialized female adolescent athletes. *Front Pediatr* 7: 268, 2019.
12. DiCesare C, Montalvo A, Foss K, Thomas S, Hewett T, Jayanthi N, and Myer G. Sport specialization and coordination differences in multisport adolescent female basketball, soccer, and volleyball athletes. *J Athl Train* 54: 1105-1114, 2019.
13. DiFiori J, Benjamin H, Brenner J, Gregory A, Jayanthi N, Landry G, and Luke A. Overuse injuries and burnout in youth sports: a position statement from the American Medical Society for Sports Medicine. *Br J Sports Med* 48: 287-288, 2014.
14. Dobbs I, JL O, Wong M, Moore I, and Lloyd R. Effects of a 12-week training program on isometric and dynamic force-time characteristics in pre– and post–peak height velocity male athletes. *J Strength Cond Res* 34: 653-662, 2020.
15. Faigenbaum A. Strength training for children and adolescents. *Clin Sports Med* 19: 593-619, 2000.
16. Faigenbaum A, Farrell A, Fabiano M, Radler T, Naclerio F, Ratamess N, Kang J, and Myer G. Effects of integrative neuromuscular training on fitness performance in children. *Pediatr Exerc Sci* 23: 573-584, 2011.
17. Faigenbaum A, Lloyd R, and Oliver J. *Essentials of Youth Fitness: American College of Sports Medicine.* United States of America: Human Kinetics 2020.239-259
18. Faigenbaum A, Lloyd R, and Oliver J. *Essentials of Youth Fitness: American College of Sports Medicine* United States of America: Human Kinetics 2020.43-65

19. Faigenbaum A, Milliken L, Cloutier G, and Westcott W. Perceived exertion during resistance exercise by children. *Percept Mot Skills* 98: 627-637, 2004.

20. Faigenbaum A and Myer G. Pediatric resistanee training benefits, coneerns,and program design considerations. *Curr Sports Med Re* 9: 161-168, 2010.

21. Fanchini M, Ferraresi I, Petruolo A, Azzalin A, Schena F, and Impellizzeri F. Is a retrospective RPE appropriate in soccer? Response shift and recall bias. *Sci & Med Football* 1: 53-59, 2017.

22. Fernandez-Fernandez J, Granacher U, Sanz-Rivas D, Sarabia M, Hernandez-Davo J, and Moya M. Sequencing effects of neuromuscular training on physical fitness in youth elite tennis players. *J Strength Cond Res* 32: 849–856, 2017.

23. Foster C, Florhaug J, Franklin J, Gottschall L, Hrovatin L, Parker S, Doleshal P, and Dodge C. A new approach to monitoring exercise training. *J Strength Cond Res* 15: 109–115, 2001.

24. Greenwald J. Mental Skills Training for Tennis Players: An Added Skill Set for the Strength and Conditioning Coach. *Strength Cond J* 31: 94-97, 2009.

25. Haff G, ed. *Periodisation strategies for youth athletes.* Oxon, UK: Routledge, 2020.288-299

26. Harrison C, Eisennmann J, and Knight C. *Creating Hollistic Environments for Young Athletes.* New York: Routledge, 2020.362-378

27. Harrison C and McGuigan M, eds. *Monitoring and Assessment of Young Athletes.* Oxon: Routledge, 2020.62-76

28. Hewett T, Myer G, and Ford K. Anterior cruciate ligament injuries in female athletes: Part 1, mechanisms and risk factors. *Am J Sports Med* 34: 299-311, 2006.

29. Jayanthi N, LaBella C, Fischer D, Pasulka J, and LR. D. 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.

30. 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.

31. Johnson J. Overuse injuries in young athletes: Cause and prevention. *Strength Cond J* 30: 27-31, 2008.

32. Khamis H and Roche A. Predicting adult stature without using skeletal age - the Khamis-Roche method. *Pediatrics* 94: 504-507, 1994.

33. Kliethermes S, Nagle K, Cote J, Malina R, Faigenbaum A, Watson A, Feeley B, Marshall S, LaBella C, Herman DC, Tenforde A, Beutler AI, and Jayanthi N. Impact of youth sports specialisation on career and task-specific athletic performance: a systematic review following the American Medical Society for Sports Medicine (AMSSM) Collaborative Research Network's 2019 Youth Early Sport Specialisation Summit. *Br J Sports Med* 54: 221-230, 2020.

34. LaPrade R, Agel J, Baker J, Brenner J, Cordasco F, Cote J, Engebretsen L, Feeley B, Gould D, Hainline B, Hewett T, Jayanthi N, Kocher M, Myer G, Nissen C, Philippon M, and Provencher M. Aossm early sport specialization consensus statement. *Orthop J Sports Med* 4: 1-8, 2016.

35. Lesinski M, Prieske O, and Granacher U. Effects and dose-response relationships of resistance training on physical performance in youth athletes: a systematic review and meta-analysis. *Br J Sports Med* 50: 781-795, 2016.

36. Ljach W. High-performance sport of children in Russia. *Leistungssport* 27: 37-40, 1997.

37. Lloyd R, Cronin J, Faigenbaum A, Haff G, Howard R, Kraemer W, Micheli L, Myer G, and Oliver J. The national strength and conditioning association position statement on long-term athletic development. *J Strength Cond Res* 30: 1491–1509, 2016.

38. Lloyd R, Faigenbaum A, Stone M, Oliver J, Jeffreys I, Moody J, Brewer C, Pierce K, McCambridge T, Howard R, Herrington L, Hainline B, Micheli L, Jaques R, Kraemer W, McBride M, Best T, Chu B, Alvar B, and Myer G. Position statement on youth resistance training: The 2014 International Consensus. *Br J Sports Med* 48: 498-505, 2014.
39. Lloyd R, Meyers R, and Oliver J. The natural development and trainability of plyometric ability during childhood. *J Strength Cond Res* 3: 23-32, 2011.
40. Lloyd R, Moeskops S, Cropley B, and Faigenbaum A. *Coaching Young Athletes.* New York: Routledge, 2020.77-100
41. Lloyd R, Moeskops S, and Granacher U, eds. *Motor Skill Training in Young Athletes.* London: Routledge, 2020.101-130
42. Lloyd R, Oliver J, Faigenbaum A, Myer G, and De Ste Croix M. Chronological age vs. biological maturation- implications for exercise programming in youth. *J Strength Cond Res* 28: 1454–1464, 2014.
43. Malina R. Early sport specialization: Roots, effectiveness, risks. *Curr Sports Med Rep* 9: 364-371, 2010.
44. Malina R, Bouche R, and Bar-Or O. *Growth, Maturation, and Physical Activity.* Champaign: Human Kinetics, 2004.277-553
45. Malina R, Cumming S, Rogol A, Coelho ESM, Figueiredo A, Konarski J, and Koziel S. Bio-banding in youth sports: Background, concept, and application. *Sports Med* 49: 1671-1685, 2019.
46. Malina R, Ignasiak Z, Rożek K, Sławińska T, Domaradzki J, Fugiel J, and Kochan K. Growth, maturity and functional characteristics of female athletes 11 - 15 years of age. *Human Movement* 12: 31-40, 2011.
47. Malina R and Koziel S. Validation of maturity offset in a longitudinal sample of Polish boys. *J Sports Sci* 32: 424-437, 2014.
48. Malina R and Koziel S. Validation of maturity offset in a longitudinal sample of Polish girls. *J Sports Sci* 32: 1374-1382, 2014.
49. Malisoux L, Frisch A, Urhanusen A, Seli R, and Theisen D. Monitoring of sport participation and injury risk in young athletes. *J Sci Med Sport* 16: 504-508, 2013.
50. Marina M and Jemni M. Plyometric training performance in elite-oriented prepubertal female gymnasts. *J Strength Cond Res* 28: 1015-1025, 2014.
51. Martin E, Ewing M, and Oregon E. Sport experiences of division I collegiate athletes and their perceptions of the importance of specialization. *High Ability Studies* 28: 149–165, 2017.
52. Meyers R, Oliver J, Hughes M, Cronin J, and Lloyd R. Maximal sprint speed in boys of increasing maturity. *Pediatr Exerc Sci* 27: 85-94, 2015.
53. Mirwald R, Baxter-Jones A, Bailey D, and Beunen G. An assessment of maturity from anthropometric measurements. *Med Sci Sports Exerc* 34: 689–694, 2002.
54. Moesch K, Elbe A, Hauge M, and Wikman J. Late specialization: The key to success in centimeters, grams, or seconds (cgs) sports. *Scand J Med Sci Sports* 21: e282-290, 2011.
55. Moeskops S, Oliver J, Read P, Cronin J, Myer G, and Lloyd R. The physiological demands of youth artistic gymnastics; applications to strength and conditioning. *Strength Cond J* 41: 1-13, 2019.
56. Moeskops S, Oliver J, Read PJ, Myer G, and Lloyd R. The influence of biological maturity on sprint speed, standing long jump and vaulting performance in young female gymnasts. *Int J Sport Physiol* 4: 1-8, 2021.

57. Moeskops S, Read P, Oliver J, and Lloyd R. Individual responses to an 8-week neuromuscular training intervention in trained pre-pubescent female artistic gymnasts. *Sports* 6: 128-142, 2018.
58. Moore S, McKay H, Macdonald H, Nettlefold L, Baxter-Jones A, Cameron N, and Brasher P. Enhancing a somatic maturity prediction model. *Med Sci Sports Exerc* 47: 1755-1764, 2015.
59. Mostafavifar A, Best T, and Myer G. Early sport specialisation, does it lead to long-term problems? *Br J Sports Med* 47: 1060-1061, 2013.
60. Myer G, Faigenbaum A, Chu D, Falkel J, Ford K, Best T, and Hewett T. Integrative training for children and adolescents: Techniques and practices for reducing sports-related injuries and enhancing athletic performance. *Phys Sportsmed* 39: 74-84, 2011.
61. Myer G, Ford K, Divine J, Wall E, Kahanov L, and Hewett T. 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.
62. Myer G, Jayanthi N, DiFiori J, Faigenbaum A, Kiefer A, Logerstedt D, and Micheli L. Sports specialization, part II: Alternative solutions to early sport specialization in youth athletes. *Sports Health* 8: 65-73, 2016.
63. Normand J, Wolfe A, and Peak K. A review of early sport specialization in relation to the development of a young athlete. *Int J Kin Sport Sci* 5: 37-42, 2017.
64. Oliver J, Brady A, and Lloyd R, eds. *Well-being of Youth Athletes.* Oxon: Routledge, 2014.214-223
65. Pasulka J, Jayanthi N, McCann A, Dugas LR, and LaBella C. Specialization patterns across various youth sports and relationship to injury risk. *Phys Sportsmed* 45: 344-352, 2017.
66. Quatman C, Ford K, Myer G, and Hewett T. Maturation leads to gender differences in landing force and vertical jump performance: a longitudinal study. *Am J Sports Med* 34: 806-813, 2006.
67. Quatman-Yates C, Myer G, Ford K, and Hewett T. A longitudinal evaluation of maturational effects on lower extremity strength in female adolescent athletes. *Pediatr Phys Ther* 25: 271-276, 2013.
68. Radnor J, Moeskops S, Morris S, Matthews T, Kumar N, Pullen B, Meyers R, Pedley J, Gould Z, Oliver J, and Lloyd R. Developing athletic motor skill competencies in youth. *Strength Cond J* 42: 54-70, 2020.
69. Radnor J, Oliver J, Waugh C, Myer G, Moore I, and Lloyd R. The influence of growth and maturation on stretch-shortening cycle function in youth. *Sports Med* 48: 57-71, 2018.
70. Read P, Bishop C, Brazier J, and Turner A. Performance modeling: A system-based approach to exercise selection. *Strength Cond J* 38: 90-97, 2016.
71. Read P and Lloyd R. Strength and conditioning considerations for golf. *Strength Cond J* 36: 24-33, 2014.
72. Read P, Lloyd R, and Oliver J. Seven pillars of prevention: Effective strategies for strength and conditioning coaches to reduce injury risk and improve performance in young athletes. *Strength Cond J* 42: 120-128, 2020.
73. Read P, Oliver J, Myer G, De Ste Croix M, Belshaw A, and Lloyd R. Altered landing mechanics are shown by male youth soccer players at different stages of maturation. *Phys Ther Sport* 33: 48-53, 2018.
74. Read P, Oliver J, Myer G, and Lloyd R, eds. *Reducing Injury Risk in Young Athletes.* Oxon: Routledge, 2020.336-361
75. Rees T, Hardy L, Gullich A, Abernethy B, Cote J, Woodman T, Montgomery H, Laing S, and Warr C. The great british medalists project: A review of current

knowledge on the development of the world's best sporting talent. *Sports Med* 46: 1041-1058, 2016.

76. Root H, Marshall A, Thatcher A, Valier A, Valovich McLeod T, and Bay R. Sport specialization and fitness and functional task performance among youth competitive gymnasts. *J Athl Train* 54: 1095-1104, 2019.

77. Scantlebury S, Till K, Atkinson G, Sawczuk T, and Jones B. The within-participant correlation between s-RPE and heart rate in youth sport. *Sport Med Int Open*: 195–199, 2017.

78. Scantlebury S, Till K, Sawczuk T, Phibbs P, and Jones B. Navigating the complex pathway of youth athletic development; Challenges and solutions to managing the training load of youth team sport athletes. *Strength Cond J* 42: 100-108, 2020.

79. Schwellnus M, Soligard T, Alonso JM, Bahr R, Clarsen B, Dijkstra HP, Gabbett TJ, Gleeson M, Hagglund M, Hutchinson MR, Janse Van Rensburg C, Meeusen R, Orchard JW, Pluim BM, Raftery M, Budgett R, and Engebretsen L. How much is too much? (part 2) international olympic committee consensus statement on load in sport and risk of illness. *Br J Sports Med* 50: 1043-1052, 2016.

80. Stratton G and Oliver J, eds. *The Impact of Growth and Maturation on Physical Performance.* Oxon: Routledge, 2020.3-20

81. Till K, Eisennmann J, Emmonds S, Jones B, Mitchell T, Cowburn I, Tee J, Holmes N, and Lloyd R. A coaching session framework to facilitate long-term athletic development. *Strength Cond J* 43: 43-55, 2020.

82. Valovich McLeod T, Decoster L, Loud K, Micheli L, Parker J, Sandrey M, and White C. National Athletic Trainers' Association position statement: prevention of pediatric overuse injuries. *J Athl Train* 46: 206-220, 2011.

83. Warren A, Williams S, McCaig S, and Trewartha G. High acute:chronic workloads are associated with injury in England & Wales Cricket Board Development Programme fast bowlers. *J Sci Med Sport* 21: 40-45, 2018.

84. Williams C, Oliver J, Lloyd R, and Granacher U, eds. *Talent Development.* Oxon: Routledge, 2020.45-61