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Training the Developing Brain Part II: Cognitive Considerations for Youth Instruction and Feedback

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Abstract

Growing numbers of youth participating in competitive, organized physical activity has led to a concern for the risk of sports related injuries during important periods of human development. Recent studies have demonstrated the ability of Integrative Neuromuscular Training (INT) to enhance athletic performance and to reduce the risk of sports related injuries in youth. Successful implementation of INT necessitates instruction from knowledgeable and qualified instructors who understand the unique physical, cognitive and psychosocial characteristics of youth to provide appropriate training instruction and feedback. Principles of a classical theory of cognitive development provide a useful context for discussion of developmentally appropriate methods and strategies for INT instruction of youth. INT programs that consider these developmentally appropriate approaches will provide a controlled, efficacious environment for youth to improve athletic performance and to reduce risk of sports related injury; thus, promoting a healthy, active lifestyle beyond an individual's formative years.

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INTRODUCTION

Youth are participating in athletic competition at greater numbers than ever before, and this has led to a growing concern for the risk of sports related injuries during important periods of human development. (35, 52, 57) As a result, there is a profound need for age appropriate and evidence–based injury prevention training programs. Accordingly, preparatory training of youth for formal physical activity is a topic of great interest as the number of program participants is increasing and these participants are initiating training at younger ages. (2, 27, 42, 52) A professionally designed training program that is based on the principles of pediatric exercise science and that considers a participant's level of psychosocial development may circumvent sports-related injuries and promote favorable performance outcomes.

Recent studies have demonstrated that Integrative Neuromuscular Training (INT)—a conceptual training model that incorporates general and specific strength and conditioning activities— has the ability to enhance physical fitness and performance and likely reduces the risk of sports related injuries in youth. (17, 18, 22, 52) INT activities and exercises are focused to promote the development of neurocognitive processing and visual-motor abilities, which are further improved by a qualified instructor's appropriate delivery of corrective feedback and interventions for identified functional deficits. (52) Evidence strongly suggests that when implemented appropriately, INT provides physiological and psychological benefits to a child as he or she transitions to adulthood. (1, 33, 51, 61) We have previously discussed the principles of human development that must be considered for INT participation and identified how cognitive and perceptual-motor developments influence the training of youth. (52) In the present commentary, we attempt to build upon this discussion by presenting an instructional framework foundation for the design and implementation of INT for specific stages of youth development from early childhood through the adolescent years.

CONSIDERATIONS BEFORE INITIATING INT

The cornerstone of successful INT implementation is employing knowledgeable instructors, including physical education teachers and trainers who understand the unique physiological and psychosocial characteristics of youth, to provide developmentally appropriate training instruction and feedback to optimize outcomes. (52) It is generally agreed that participants of structured sport must be able to comprehend and handle the attentional demands of coaching instructions and rules. (52, 53) This concept holds true for INT programs as well. A child that is deemed ready for structured sports participation would typically be eligible for enrollment in INT. (48, 53) Research indicates that the type and frequency of physical activity for children as young as 3 years of age can successfully (or unsuccessfully) position them to progress more quickly through periods of skill acquisition, promote the development of both cognitive and perceptual-motor control more efficiently, and provide the foundation for a healthy and active lifestyle well beyond their adolescent years. (7, 13, 28, 48)

It is understood that not all children will begin and progress through physical training programs at the same chronological age or stage of development due to disparities in

genetics, abilities, resources, education, and opportunities. (23, 53) As previously mentioned, there are neurodevelopmental thresholds (or milestones) that a child must reach before they can begin and progress through INT. (14, 52) For instance, a child must have the intellectual capacity to comprehend instruction and feedback and to maintain attention during training. Sufficient proprioceptive abilities and intellectual capacity is required prior to INT for the child to appropriately respond to corrective feedback to improve deficiencies in form, strength and mechanics. Beyond limitations to INT outcomes, if a child were to begin INT before reaching these developmental thresholds, their safety could potentially be put at risk when training in a high-risk environment. (14, 21) A strong point in favor of this argument is an American Academy of Pediatrics (AAP) statement that states, when summarized, children are not developmentally ready for swimming lessons until the age of four. (73) It is thought that children below this age may lack both substantial neuromuscular control and the ability to comprehend basic instruction. Swimming, in this example, has relatively complicated instructions and requires honing the coordination between complex motor actions and breathing; and the environment can be hazardous if the individual is not of sufficient developmental maturity and appropriately supervised. Prior to the achievement of necessary developmental thresholds, whether due to insufficient strength and neuromuscular control or an inability to understand instructions, risk of injury during activities such as swimming may be increased. Although INT lessons are not classically instructed in high-risk environments such as swimming pools, the AAP statement supports the notion that children younger than the age of four may lack important developmental abilities to comprehend instructions to support training outcome potential and safety.

STAGES OF YOUTH DEVELOPMENT

The present commentary expands upon our previously published review by drawing primarily from principles of Piaget's classical theory of cognitive development. (24, 52, 63, 66) Although more contemporary theories have expanded considerably on the complex gene-environment interactions that determine the course of human development, developmental psychologist Jean Piaget's work nevertheless provides a useful context for a discussion of developmentally appropriate methods for the implementation and instruction of youth INT programs. (63) Refer to Figure 1 for the relationship of Piaget's developmental stages to the training stages discussed in this commentary. It is important to note that the ages that make up each of the proposed developmental training stages are only guidelines along a continuum, and that the perceptual-motor and cognitive development of each individual child may be more important for determining the child's preparedness for initiation of and progression through INT.

These principles are instilled here to formulate the context of INT implementation across the spectrum of childhood through adolescence. This framework suggests broad guidelines for instruction and feedback to optimize training outcomes through different phases of a child's physical and cognitive development (Figure 2). The reciprocity between cognitive and motor development requires such a discussion, given that cognitive development strongly depends on the child's capacity for movement skill acquisition, (24) just as motor development depends heavily on intellectual capacities. (62) The following sections explain

and provide examples of advised developmentally appropriate activities, instruction methods, and feedback strategies to conduct a successful INT program for youth.

EARLY CHILDHOOD

Preoperational Stage Ages 2–6

Youth in the early childhood stage can greatly benefit from introduction to and regular participation in physical activity prior to their development of physical and cognitive capacities necessary for INT. The United States Department of Health and Human Services guidelines indicate that pre-school centers are targeted resources to help influence beneficial motor skill and primal strength development. (71) Instead of organized sports during the pre-school years, it is encouraged to create regular, enjoyable opportunities for children to engage in informal games and physical play activities that enhance basic motor skills and that allow them to explore their movement capabilities within various environmental contexts. (28, 47, 48) It is the authors' contention that the general promotion of 60 minutes of daily moderate to vigorous physical activity (MVPA) is too general and a non-specific prescription for children. The current recommendations do not describe the type and frequency of activities or exercises, especially for strength training, in which a child should participate to best promote a lifelong healthy and active lifestyle. The United States Physical Activity Guidelines for Americans and the World Health Organization guidelines provide a detailed prescription for duration, frequency, and intensity of aerobic physical activity recommendations, but only provide generalized recommendations for muscle-strengthening activities to be performed 3 times a week. (72, 74) While others make no mention of muscle-strengthening activities, (12) some academic societies now include noteworthy recommendations for the development of fundamental movement skills, although they do not provide prescriptive details for resistance exercise. (5, 70)

Concomitant with the limited detail on motor skill and strength prescription guidelines, there is also limited focus on the type of movement as it relates to the development of prerequisite motor skills in youth participating in training and sport. The type of movement or activity is critical to support the development of essential fundamental motor skills. (56, 69) However, the prescription of any type of physical activity for children should be within the limits of their physical and cognitive abilities to facilitate skill development, promote enjoyment, and ensure safety. (16)

Informal physical activity, such as play, allows children to advance verbal and non-verbal communication skills through interaction with peers, while they develop rudimentary motor skills. Adults should emphasize enjoyable experiences of physical activity for young children as this is imperative to promote and fortify the child's affinity for future physical activity and exercise. Further, it is important for adults to provide increased supervision to children under the age of four during any physical activity because they may lack an awareness of their physical capabilities and a rational understanding of the inherent dangers of their environment. During unsupervised physical activity, including play, youngsters' curiosity and unfamiliarity with the physical world may increase the potential for injury; therefore, adult supervision should be available and vigilant when appropriate. (21, 32)

Typically, children under six years of age are still acquiring basic neuromotor, language, and cognitive skills, in combination with foundational motor skills such as postural control and basic locomotor (e.g., gait) coordination. (62) As children develop the necessary cognitive and perceptual-motor skills necessary for stable movement patterns, exposure to informal games and activities that mimic INT training progressions can reduce apprehension for future training exercises. For example, classic children's games such as "hopscotch" and "leapfrog" can introduce children to simple plyometric movements that can lay formative locomotor groundwork prior to teaching formal plyometric drills and techniques. It is estimated that children near the end of the preoperational stage, typically around 6 years of age, have developed the physical and cognitive abilities to run smoothly, skip, hop on one foot several times, and throw a ball. (3, 8, 60). It is also conceivable that children who have been exposed to more frequent physical activity may exhibit critical improvements in endurance and motor coordination during the early childhood stage. (14) These physical improvements, in conjunction with neurodevelopmental milestones, are important prerequisites for the child to begin INT participation with competence and confidence. (8)

An individual during the early childhood stage is quite egocentric. (63) That is, the child regards their needs and desires as their primary center of focus and holds a more narrow perspective of the world. (60, 63) The child also exhibits little regard for the vantage, interests, or beliefs of others and maintains a relatively short attention span with limited selective attention. (63) Given the egocentric nature of children at this point in cognitive development, they can become easily frustrated when their demands and desires are not immediately met. (63) It is essential that instructors and supervisors present physical activities and games in a fun and captivating manner to fulfill children's attentional and motivational needs in order to acquire optimal focus and engagement. Children may also lack the ability to internally manipulate and transform information in a logical way; therefore, prompting instructions by asking the child to "play" or "pretend" may facilitate desirable performance and outcomes. (63) Instructing children to mimic familiar poses, such as those of animals, may assist them in learning prerequisite fundamental movement form in games and activities before initiating formal exercise (Figure 1; Early Childhood Stage). For example, a child can be instructed to crouch down like a frog or stand on one foot like a flamingo. Teachers and trainers must be versatile and creative to present fun, captivating and safe activities for young children to informally practice fundamental motor and communication skills.

Another consideration prior to INT is that children often develop perceptual-motor and cognitive processes at a rapid and somewhat irregular rate. (65) This is a particularly important consideration during activities that probe a child's reaction times, mental processing speeds, and attentional limitations. At this age, children's mental processing speeds and reaction times are relatively slower; hence, they may perform better if they are conscious of a planned event (e.g., if they are aware of where a ball will land, they will be more likely to catch it) rather than unanticipated or unplanned events. (7) Priming a child during the early childhood stage with appropriate informal physical activities to stimulate motor and cognitive development may improve their ability to achieve optimal motor capacity later in life. (48)

LATE CHILDHOOD

Early Concrete Operational Stage Ages 7–9

Introducing INT during the late childhood stage brings many critical advantages. Most importantly, children at this developmental stage will learn and execute novel, basic movements with more ease, given their relatively higher neuroplasticity compared to older children and adolescents. (52) The early refinement of movement patterns may allow for more efficient advancement through the early stages of INT, (52) and this may enable a child to advance to more complex and intense exercises at younger ages than their less experienced peers. (53) Unlike other pathologies that can be treated pharmacologically, there are no medications to treat deficiencies in movement skills. Instead, an intervention strategy that includes resistance and motor skill training at this stage of development may prevent the eventual upsurge in neuromuscular deficiencies and high risk behaviors that can propagate during this critical period of life and ultimately lead to negative health consequences such as obesity. (26, 34)

A study by Benguigui and Ripoll provided evidence that training athletes as young as 7 years of age could improve their skills and techniques to match those of older children. (6) This study showed that adaptations from training can be acquired at young ages once certain cognitive and neurodevelopmental thresholds have been reached. (6) These findings make a strong case that advanced training can be beneficial for children even at this early stage. More specifically, researchers reported that the addition of 12 minutes of INT to physical education class positively influenced measures of motor performance in children who were in this stage of development. (17)

Generally by 7 years of age, improved cognitive, biological, and neuromuscular abilities make it possible for children to participate in both structured and spontaneous physical activity, with a direct relation between the child's level of development and their preparedness for more advanced physical activities such as INT. Musculoskeletal and nervous system development during this stage facilitates gross motor patterns that are more similar to that of an adult. (38, 60) Movement patterns may become more refined, graceful, and rhythmic, and biological maturation leads to improved posture, balance, and reaction speed. (28, 29) Gender differences at this stage are still not and will not substantially differentiate until the onset of puberty, which comprises rapid transformation and development. (29, 34) Children in this developmental time point also have improved cognitive abilities such as an expanded vocabulary, improved memory, enhanced visual acuity, an improved auditory sense, and heightened motor control. (13, 28, 29, 68) They are better able to integrate visual, vestibular, and proprioceptive cues at more sophisticated levels. (13, 28, 29, 68) INT exercises should be planned, structured, repetitive, and appropriately progressed to improve or maintain components of fundamental mechanics and physical fitness. (9) However, starting INT at this level comes with a few caveats in order for the program to be most beneficial.

Instructions and rules can be more complex but still must be explicit and relatable to the task. Immediate feedback is imperative at this stage because these children still do not have a strong memory capacity or attention span. Children will also not have much experience

with training and physical activity and thus rely on coaching instruction and cuing to obtain correct form and technique. (52) Children still tend to think in discrete extremes (e.g., black or white, right or wrong) and such extremes can be utilized for instruction (e.g., demonstrate gross errors in demonstrated movements). Furthermore, INT relies heavily on appropriate and immediate feedback from a qualified professional to correct and instill proper form and technique. Children may quickly become frustrated and/or angered when they are not able to perform a task correctly. Thus, it is important to use feedback that emphasizes praise for good effort (as opposed to perfect execution) so that the experience is positive, rewarding, and enjoyable. INT feedback should remain mostly positive to reinforce correct technique, form, and effort as many children struggle with criticism. (60, 68) Reinforcement may prove more beneficial as a feedback strategy to instill a behavior compared to constructive criticism or punishment.

Individual training may be advantageous to maximize focus and effort during early exposure to planned exercise, despite limitations to social interaction among peers. However, in many cases, group training is more likely due to limited resources. In this case, groups should be kept to fairly small numbers (2–6 per group) to support children to maintain focus and to allow the instructor to provide adequate supervision and to supply sufficient feedback to each participant. (60, 68) It is essential that children consistently demonstrate proper fundamental technique before moving on to more advanced or intense exercise variations and progressions (e.g., unanticipated challenges or events).

Training may be most beneficial if instructions are short, explicit, and are comprised of basic vocabulary, as these children typically still have a relatively limited vocabulary and struggle to comprehend complex sentences. (60, 65) Children in the late childhood stage are also developing their cognitive ability to remember and recall basic information. For this reason, children in this stage are less likely to recall previous training sessions and specific technique criteria. (14, 36) Thus, it may be important to repeat many of the instructions to an exercise, drill, or game each time children are expected to participate. It can also be beneficial to ask the children about rules and objectives through simple questions to fortify comprehension and recall. Accordingly, songs, rhymes, and other mnemonic devices may assist with the retention of information for this age group, (60) while excessive background noise or employing several instructors to deliver directions can contribute to confusion for the child. (38) It may be advantageous to assign verbal instruction to one trainer that can speak clearly and at an appropriate volume for the environment. Background music or sound effects may prove detrimental during instruction and should be minimized or removed altogether, as this can lead to further distraction or confusion for the child.

Physical cuing (e.g., promoting correct form via physical manipulation or stimuli) may facilitate desirable training outcomes, as children in this stage tend to respond well to these prompts, in contrast to verbal cuing (Figure 2; Late Childhood Stage). (60) Drills and exercises may be further enhanced for this age group through the integration of visual aids and props, such as colored cones or place markers for starting and ending positions. Verbal cues may be difficult for children in this stage to comprehend especially if they are focused on a concurrent physical task. To improve verbal communication, strategies that utilize relatable models or common analogies may prove useful as children of this stage are better

able to make connections between words and movements. The advantage is that such terms and analogies may be more relatable for a young child than classic anatomic or biomechanical terminology often used in training for older athletes.

Children in the late childhood stage are developing the ability to use inductive logic to better understand events and their outcomes. (36, 63) However, these children may still be predominantly “in the moment” thinkers. (28) That is, the immediate present is of utmost importance to them and, as a result, they may have difficulty understanding longer-term objectives of activities or exercises (e.g., health or performance related outcomes from training). (43, 63) Thus, motivation will most often originate from present, task-specific enjoyment rather than from the future benefits of neuromuscular training. (63) These children may also have difficulty with self or peer performance comparisons. (28, 29) Therefore, it may be advantageous to have the child focus on the present scenario and to avoid prompting these children to attempt to make comparisons for instructive purposes.

Comprehensive training with task and exercise variety has shown to be beneficial for both injury prevention and future physical performance of children. (17, 47) Specifically, the National Association for Sport and Physical Education Guidelines for Participation in Youth Sport Programs suggest that delayed sports specialization provides enhanced opportunities for more well-rounded psychological and social youth development. (11, 31, 45) As a result, youth may be less drawn to a “specific sport culture” that is more focused on winning rather than the long-term physical development of the athletes. (31, 39, 40, 45) In addition to psychosocial benefits, children in late childhood who participate in multiple sports can gain expanded exposure and practice to various general and specific skills sets. Diverse sports participation, along with INT to enhance muscle strength and to support motor skill development, may reduce the likelihood of sports-related injuries, especially repetitive movement injuries, in young athletes. (31, 45) It is not surprising that many elite athletes at the collegiate and professional level participated in a variety of sports during childhood and early adolescence. (44)

While ensuring safety in the training environment is important at all stages of development, it should be an especially strong point of emphasis at this stage. Improved cognitive abilities and creativity may lead some children to believe that they are skilled beyond their actual capabilities. As a result, exercises and activities should be appropriately prescribed and closely monitored to reduce training injury risk. (21, 55) Extra care and attention are needed when children exercise in a room with adult training equipment, as accidental injuries (e.g., dropping weights and pinching fingers) have been reported. (21, 55) Additionally, as children are still honing their motor skills, they may have limited control over the direction or force they inflict on an object (e.g., throwing or kicking a ball). (29, 67) Thus, it is important to maintain appropriate safety precautions, as flying objects can be harmful to other children and adolescents in a large group training session.

PREADOLESCENCE

Late Concrete Operational Stage Ages 10–11

Preadolescence constitutes the years of development between childhood and adolescence. Preadolescents have an improved ability to think in terms of the past, present, and future. (24, 63) An instructor can take advantage of this developmental milestone to maximize positive training outcomes. To instill correct technique, it is recommended that an instructor review previous exercise performances during subsequent sessions. Corrective feedback from instructors will become more essential as preadolescents are more likely to understand verbal feedback and will be more capable of self-adjusting form and technique. Youth in this stage may still remain sensitive to negative performance comparisons with their peers and may become easily discouraged or embarrassed. It is important to reinforce positive performance to enhance self-confidence and continued participation in physical activity.

For preadolescents, motivation for training is now a hybrid of fun-oriented and goal-oriented activities. Many individuals in this age group are able to comprehend the benefits of training; however, the benefits may not provide the necessary incentives for full engagement. Feedback should be delivered through a well-balanced combination of praise and constructive criticism. Youth in this stage of development have more fully developed cognitive processes, such as heightened intellect, self-correction, comparison and the ability to understand the purpose behind consequences. (60) However, preadolescents may have limited experience with constructive criticism in physical activity, so it is important to carefully and systematically introduce this method of feedback into their training instruction. For those athletes new to constructive criticism during training, it can be beneficial to first provide positive feedback on what the athlete did correctly during an exercise before delivering constructive criticism on technique criteria that require improvement. In addition, a positive tone should be used when relaying constructive criticism to convey encouragement rather than disappointment.

Preadolescents may also begin to showcase capabilities to self-correct their own technique. These athletes can greatly benefit from watching an instructor demonstrate desired technique to compare to their own technique to target criteria to improve (Figure 1; Preadolescence Stage). Moreover, supplementary instructive methods such as using mirrors and videos may prove useful as preadolescents can begin to self-adjust their performance to improve movement and functional strategies. As young athletes in this stage are just beginning to learn and apply these self-corrective methods, coaches and trainers may further assist the athlete by pointing out the area of most concern or using guided questions to help the athlete focus on specific criteria.

Owing to the earlier mastery of fundamental movement skills and development of adequate levels of muscular strength, preadolescents can engage in more advanced INT exercises. Preadolescents may also benefit from increased exposure to more intense bouts of physical activity, but only if a qualified instructor is confident that an individual’s fundamental movement technique is correct and consistent. (25, 26, 48) It is also recommended to begin to use challenges and variations in training to advance motor coordination and cognitive abilities, such as reaction drills. (54) Advanced motor skills in combination with enhanced

cognitive abilities will allow preadolescents to better execute these complex, dynamic movements. The complexity of prescribed exercises is often dependent on the developmental level and training age of the athlete. (52) Despite vast improvements in physical and cognitive abilities during this stage, progressions to more intense exercises must still be regulated by an individual's ability to consistently demonstrate correct form and technique of a precursor exercise. For example, before an individual is instructed to perform intermediate levels of plyometric exercises such as broad jumps or low-level depth jumps, the athlete should demonstrate a mastery of takeoff and landing mechanics during beginner level plyometric exercises such as wall jumps and squat jumps. (10, 54)

Drills that begin to incorporate unplanned or unanticipated reactions to stimuli can be initiated during this developmental stage. It is important to recognize that maturation will significantly vary during this age, as individual children mature at different chronological ages and rates. Therefore, it is imperative that qualified trainers continually monitor training progressions in conjunction with the individual's current capabilities and skills. Game-like situation drills and simulations can be useful and stimulating for training; however, it is important to incorporate a variety of scenarios from many sports and not to over-specialize too early in an athlete's career. Involvement in competitive sports often begins to increase in duration from childhood, but sport specialization is still not recommended as it may reduce motor skill development potential and may increase risk of injury. (11, 17, 47) Formal competition should not overshadow opportunities to develop fundamental motor skills, enhance physical prowess, improve decision-making skills, and expand problem-solving skills necessary for participation in various sports and physical activities. (60) If a preadolescent has engaged in a variety of appropriate training activities, before and during maturation, they may be better poised to capitalize on the combination of consolidating factors that support motor skill performance during their post-pubertal training years. (48)

ADOLESCENCE

Formal Operational Stage Ages 12–18

Adolescence is characterized by accelerated developments in physical growth, motor skills, and higher order cognitive functions. (28, 29, 60) Individuals in this stage are undergoing puberty, which can result in greater variability of physical development and abilities. (29, 59, 60) Given the acute hormonal changes experienced during this stage, appropriately prescribed training will promote greater neural and anatomical adaptations of the neuromuscular system. (19, 37, 58, 59) Collectively, these changes may enable post-pubertal youths to generate greater overall force that enhances the performance of foundational motor skills, such as running and jumping. (15)

Gender differences significantly increase during adolescence as well. (28) Specifically, males will have greater improvement in tasks that require muscular strength, whereas females progress more in tasks that require balance and control. (28, 29, 59, 60) Throughout adolescence, males are more likely to advance in motor power performance (e.g., vertical jump) than females. (28) Thus, a benefit of INT participation, especially for female athletes, is greater gains in motor power performance than those who have not. (25, 26,41, 49, 64)

In addition to traditional resistance training exercises (e.g., squatting, deadlifting, pressing, and pulling), weightlifting movements (e.g., clean and jerk, snatch) and plyometrics can serve as safe and effective exercises for pubertal youth for the development of muscular strength and power. (69) It is essential that those responsible for instructing weightlifting movements and jumping activities to school-age youth possess sufficient practical experience teaching these exercises to adolescents, a recognized professional certification, and a level of knowledge commensurate with a college degree in exercise science or physical education. While less experienced fitness professionals can assist in the organization of youth programs, it is desirable that professionals are equipped with the level of expertise to provide technical instruction that is needed for more advanced INT programming. (20, 48)

In adolescence, the use of more technical direction can be employed for training, given the cognitive capabilities of these athletes. (58) Directions can be primarily verbal, although visual aids such as instructor demonstration or videos may still be needed for more complex exercises and drills (Figure 1; Adolescence Stage). (46, 50, 56, 69) Improved vocabulary and comprehension of biomechanical terminology allows for instructors to articulate their intentions to adolescents more easily. All details of an activity or drill may not have to be explicitly expressed for every repetition and the athlete can take part in activities that requires them to process short directions and adapt on the fly. These activities may more closely resemble sports that involve fast pace play that necessitates efficient reactions and appropriate physical responses. The use of symbols, signs, and code words can be used with mature athletes who are better able to think abstractly and multitask to offer communication in real-time during an activity. These methods can add complexity and elements of unpredictability to exercises and drills for the improvement of reasoning and reaction ability. For example, an instructor could indicate desired direction changes during a drill with hand signals. Improved mental capacity may also improve an athlete's ability to recall performances from previous training sessions, and this may allow an individual to progress more efficiently through exercise progressions. (30, 58) Furthermore, evidence-based programming from a qualified instructor can improve the effectiveness and outcome potential of an INT program for adolescents, especially if such a program can be regimentally designed for participants who are more mature and self-motivated.

Adolescents, compared to children in other stages, have an improved ability to compare their performance to that of their peers and to their own previous training sessions to identify their own strengths and weaknesses. (30, 58) At this age, athletes become more proficient at self-correction in real-time, and can readily identify correct and incorrect technique. (46, 56, 69) This capability is due to a host of cognitive and perceptual-motor factors, including the athlete's more finely tuned proprioceptive senses. (30, 58) However, specific and timely feedback from an instructor is still beneficial to the athlete's development and improvement. (47, 60) One negative consequence of improved self-awareness is that adolescents may tend to be overly concerned with self-image. (28) Anxiety over perceived comparisons among peers could hinder an athlete's motivation for participation in group training. (4, 60) It may be beneficial to arrange individuals in small groups that take ability, training-age, and gender into consideration to generate less emotionally pressured environments for training. (4) In addition, athletes that initiate INT at an earlier age may be less self-conscious of their

performances during group training than athletes that initiate INT during adolescence. Furthermore, co-ed training may add elements of distraction and heightened self-consciousness as well, and this can further hinder optimal training scenarios. However, delving into gender specific guidelines exceeds the scope of the current discussion and, regardless, such gender related differences may not greatly affect programming at this stage of development.

Feedback for adolescents can move further along the spectrum of praise to constructive criticism. Athletes can now understand the implications for constructive criticism and the purpose of its usage. For adolescent athletes who have developed more slowly, it may still be worthwhile to use praise to promote motivation and continuation of training participation. As reasoning abilities become more sophisticated, some adolescents may disagree and argue with adults' instruction or perspectives. It should be understood that this attitude is a normative transition to independence and a need to feel in control. Providing an adolescent the opportunity to choose from a range of acceptable options rather than insisting on a particular approach is much more likely to lead to cooperation with less resistance.

At this stage of development, many youth have acquired essential cognitive capabilities for analytical problem-solving and abstract patterns of thought. (28) These individuals will generally understand the underlying rationale for the selection and utility of exercises, and they will have a greater ability to comprehend health and wellness education. Qualified instructors can assist in the education of athletes on strategies to instill positive habits that promote health and wellness for lifelong physical activity. For example, older adolescents can be taught how to program workouts and how to safely perform specific exercises in absence of an INT instructor. Moreover, by using and sharing evidence-based reasoning to support intentions for exercise selection, instructors can promote an improved understanding and acceptance of exercise science in youth.

At this stage, motivation of older adolescent athletes has moved along the continuum from child-like motives (e.g., entertainment) to more mature performance related goals (e.g., personal records). Some adolescents will be self-motivated to train to improve their performance, while others may need to be educated on how exercises directly relate to improved athletic performance, especially for more complex exercises. It is also important to recognize that adolescents are still considered to be part of the youth population, so instructors should still attempt to make training entertaining and enjoyable to promote affinity for continued physical activity.

Many adolescents showcase more specific athletic talents and unique skill-sets during this stage. (28, 29) Continued participation in different activities and sports is encouraged; however, adolescents who have developed strong fundamentals and a variety of physical skills may consider sports specialization to focus more on these sport-specific skill-sets. Nonetheless, diversification likely enhances long-term performance and reduces injury risk throughout adolescence. (11, 28,29,31, 45, 60)

CONCLUSION

Training youth for competitive physical activity in a method that enhances performance, reduces injury risk, and ultimately promotes a lifetime of physical activity is an exceedingly complex process. Throughout a young athlete's development, one must not only carefully consider their changing perceptual-motor system, but also its complex relation to the developing brain. Factors such as the individual's cognitive and motor capabilities for learning movement patterns, and also the motivation for training at each developmental stage must be well understood for successful implementation of training programs and interventions. Qualified professionals who are cognizant of the physical and psychosocial uniqueness of children and adolescents are needed to successfully instruct INT programs to address the myriad challenges that arise throughout youth sport participation. The appropriate utilization of INT that appreciates age-appropriate instruction and feedback strategies throughout the developmental years provides a controlled and effective environment for youth to enhance their skills to improve athletic performance and reduce the risk of sports related injury. Most importantly, it provides a foundation for a healthy, active lifestyle beyond the formative years.

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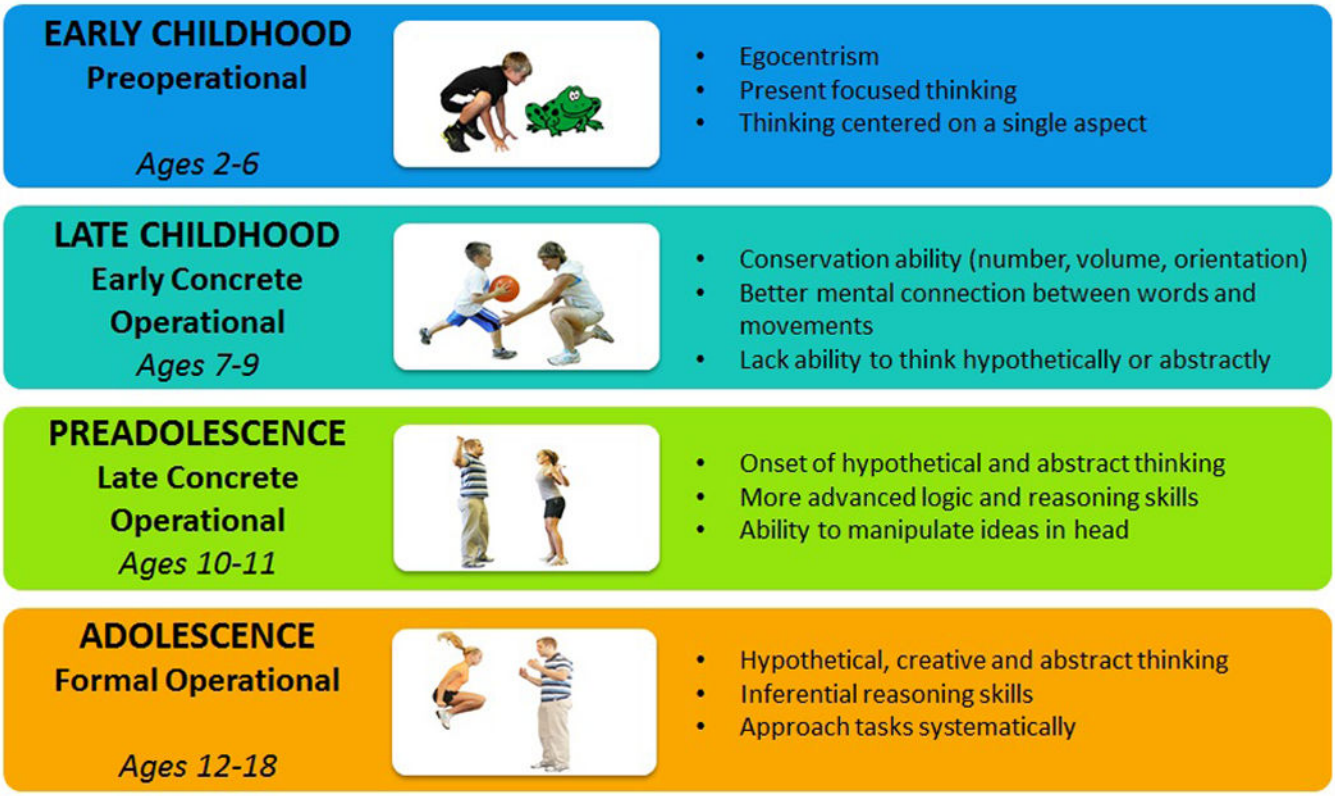

Figure 1.
Relationship of Piaget's developmental stages to the youth training stages

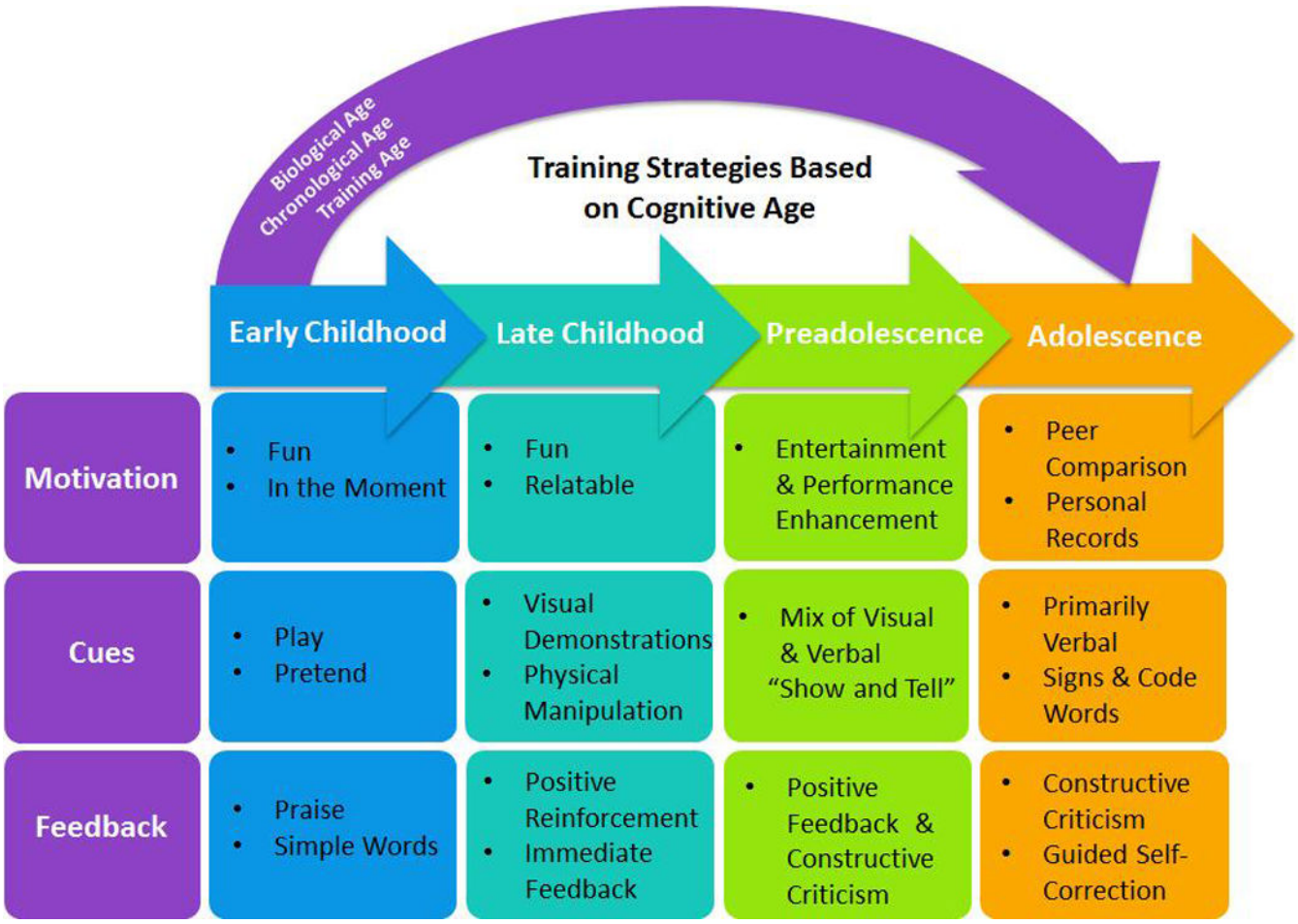

Figure 2.
Training strategies relative to motivation, cuing and feedback associated with each stage of youth development.