HOW YOUNG IS TOO YOUNG TO START TRAINING?

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LEARNING OBJECTIVES

- To introduce an integrative neuromuscular training model that can be used to enhance the health, fitness, and wellness of all children and adolescents.
- To understand the potential benefits associated with strength and conditioning programs implemented with youth to reduce injury risk and enhance motor skill development that will support a physically active lifestyle.
- To comprehend the concept of "training age" and the implications associated with systematic training beginning during early childhood.

Key words:
Children and Adolescents, Integrative Neuromuscular Training, Motor Skill Development, Injury Prevention, Sport Injuries

INTRODUCTION

Participation in organized youth sports is increasing, and the opportunities to participate in more competitive environments are happening at younger ages (1). The interest from parents and coaches to help youth enhance sports performance has fostered a concomitant growth in youth strength and conditioning, performance enhancement, and injury prevention programs in fitness centers and private training facilities. These youth training programs have raised interest and concern from parents, clinicians, coaches, and fitness professionals regarding the timing of when it might be safe or optimal to integrate more specialized physical training into youth development programs (5,14,46). Specifically, many parents ask if it is safe for their child to "lift weights" or want to know the "best age" or "when is it safe" for their child to start regular participation in more structured conditioning activities (41).

This emphasizes the long-enduring interest in the most appropriate and safest time during maturation to start specialized physical training (*i.e.,* strength and conditioning, performance enhancement, or injury prevention) with youth. Further questions also arise regarding the determination of the optimal time to initiate and progress programming of physical conditioning for children and adolescents. This review synthesizes the latest literature regarding the initiation and implementation of integrative neuromuscular training for youth. In addition, we discuss the concept of "training age" and examine the critical importance of exposing children to a variety of developmentally

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appropriate activities early in life to reduce the risk of sport-related injuries and improve health- and skill-related measures of physical fitness.

OPERATIONAL DEFINITIONS

For simplicity, the term *youth* refers to children (Tanner stages 1 and 2 of sexual maturation; approximately up to age 11 years in girls and 13 years in boys) and adolescents (Tanner stages 3 and 4 of sexual maturation; approximately ages 12 to 18 years in girls and 14 to 18 years in boys). The term *preadolescent* refers to boys and girls who have not yet developed secondary sex characteristics. *Integrative neuromuscular training* (INT) is a conceptual training model that is defined operationally herein as a training program that incorporates general (*e.g.,* fundamental movements) and specific (*e.g.,* exercises prescribed to target motor control deficits) strength and conditioning activities, including resistance training, dynamic stability exercises, core focused training, plyometric drills, and agility training that are designed specifically to enhance health and skill-related components of physical fitness (Fig. 1) (40,41).

The cornerstone of INT is age-appropriate education and instruction by qualified professionals who understand the fundamental principles of pediatric exercise science and genuinely appreciate the physical and psychosocial uniqueness of children and adolescents. INT is designed to help the youth master fundamental motor skills, improve movement mechanics, and gain confidence in their physical abilities while participating in a program that includes variety, progression, and proper recovery intervals (14,40). *Training age* is defined as the amount of time accumulated from both periodic and longitudinal participation in training programs and sport-related activities that foster the development of musculoskeletal health, basic movement patterns, and overall physical fitness.

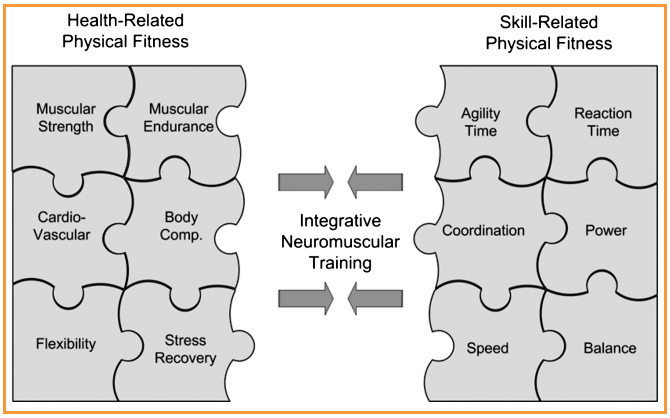

Figure 1. Integrative training model indicating a focus on the development of fundamental motor skills through activities that consolidate skill- and health-related fitness may maximize training age during preadolescence. (Reprinted from: Myer GD, Faigenbaum AD, Ford KR, Best TM, Bergeron MF, Hewett TE. When to initiate integrative neuromuscular training to reduce sports-related injuries and enhance health in youth? *Current Sports Medicine Reports* 2011; 10:157–166. Used with permission.)

THE IMPORTANCE OF TRAINING AGE

The question "*How young is too young?*" is related to the determination of timing to initiate training for school-aged youth. This is important particularly for aspiring young athletes who are often ill prepared for the physical demands of sports practice and competition. Insufficient readiness for sports practice and competition may be a consequence of the current decline in unstructured physical activity among children and adolescents in the United States and is an antecedent for increased injury risk (45–47). Although many factors can contribute to sport-related injuries in the youth (*e.g.,* previous injury, muscle imbalances, nutritional deficiencies, improper footwear), poor physical fitness exacerbated by secular trends of decreased muscular strength and fundamental movement skills (FMS) in the youth likely plays a primary role.

Deconditioning associated with growth and development can be detrimental especially as injury risk factors may manifest during maturation (19,23,43). In the absence of sufficient corresponding neuromuscular adaptation, musculoskeletal growth during maturation can influence the development of abnormal movement mechanics during certain activities (20,23). If not addressed early, these developmentally related injury risk factors may continue through adolescence and into young adulthood, thus predisposing young athletes to an increased risk of a variety of musculoskeletal injuries (24,42,45). This troubling trend underscores the importance of encouraging participation in strength-building and skill-enhancing activities in childhood to avert declines in motor skill development and neuromuscular fitness during adolescence (4).

Studies investigating the trainability of the youth with resistance and integrative-type training protocols have demonstrated consistent improvements in selected performance measures in children and adolescents following progressive training programs (9,13,15–17,26,44,48,49,55,56,67). Although chronological age has been used historically for initial participation and grouping of sports teams, it is clear that maturity-related differences in body size and motor skill performance emerge at approximately 6 to 7 years of age (38). These developmental differences in stature and skill can make programming for youth based on chronological age contentious.

In this light, somatic (body shape-related) maturational assessments have been proposed as a method to identify rapid adolescent growth (36) and to help guide program development for the youth (41). Individual determination of the percentage of adult height also has been used as a noninvasive indicator of maturity status (38). Peak height velocity is the maximum growth rate during the adolescent growth spurt, which occurs at approximately age 12 years in girls and age 14 years in boys (52,61). However, youth programs based on either biological or chronological indicators often miss the mark related to the appropriateness of the exercise selection or the design of the fitness program. Although it is beneficial to initiate INT

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programs during preadolescence *before* the period of peak height velocity, it is likely that children with earlier somatic maturation (body size growth) may be responsive particularly to INT during the growing years (40). Regular exposure to this type of training early in life will increase the training age of the youth and likely will set the stage for even greater gains in physical fitness during their postpubertal years, provided that the training program is well designed and consistent with an individual's needs, goals, and abilities. Currently, there is no evidence that indicates a minimum age for participation in INT programs. However, it generally is agreed on that participants must be able to follow coaching instructions and be able to handle the attention demands of a training program. A child that is deemed ready for structured sports participation (about age 7 or 8 years) typically would be ready for INT (5,12), although the importance of improving motor skills during the preschool years should not be overlooked (21,39).

INCREASING TRAINING AGE IN THE YOUTH

In the context of this discussion, training age relates to the length of time from initiation of regular fitness training or INT until the present time. For example, youth who begin INT at an earlier age will have a greater training age relative to their chronological age when compared with their peers who start training later. It also should be noted that youth who initiate improper or inconsistent training may not progress in training age or reap the desired benefits (Fig. 2). Of note, fitness professionals working with the youth should consider the importance of planned rest and recovery within training periods as well as periods for teaching proper technique that can facilitate rest and recovery and optimize long-term training adaptations.

Practically, training age can provide a theoretical construct that should guide the practitioner in selecting appropriate exercise criteria. Although INT programming is beneficial to children whose motor capabilities are highly "pliable" and amenable to age-appropriate interventions, youth who are not

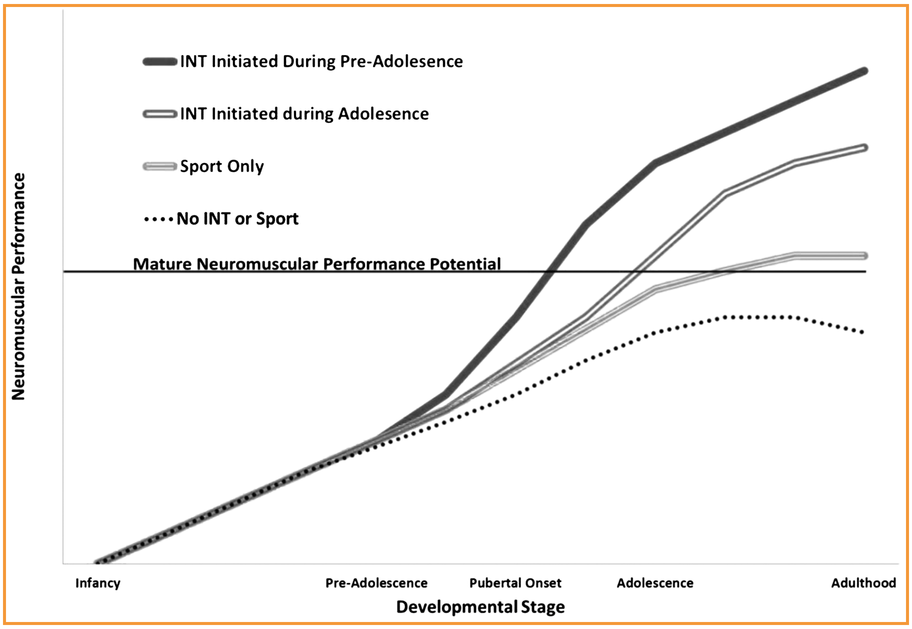
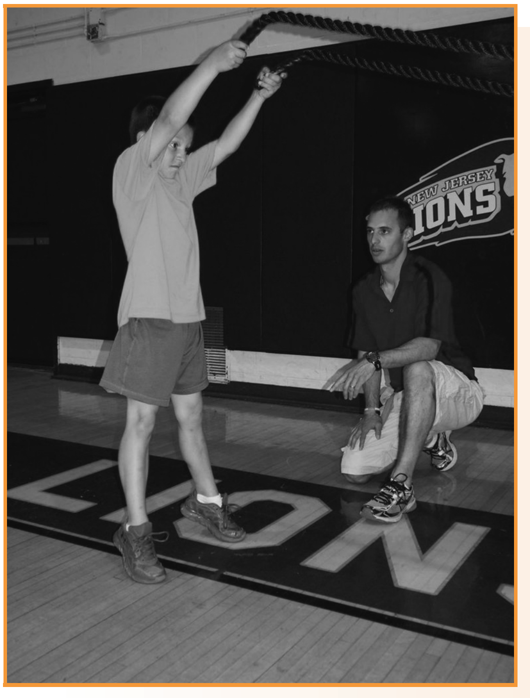


Figure 2. Conceptual model that compares the effects of integrative neuromuscular training initiated at different times in youth. The different patterned lines represent the initiation of these integrative training techniques during preadolescence (dark solid line) and adolescence (double line), which likely will improve motor capacity and performance beyond natural adult potential (without such training). It is suggested that integrative neuromuscular training initiated in preadolescence and maintained into adolescence will maximize training age and the potential to achieve optimal adulthood motor capacity. Broken lines indicate potential detrimental effects of physically inactive youth who are not exposed to the integrative training model.



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exposed to environments that enhance motor skill development are susceptible to a regression of their training age (11). As such, lapses in training because of extended periods of injury, school vacations, or sedentary lifestyle may either set the young athlete back in training age or, in extreme cases, regress the training age back to near zero. Because of this, it is important for fitness professionals who work with youth to understand the complete "sport- and training-related history" of each participant, which should include information on participation in sports and in strength and conditioning activities to gain a perspective to the overall training volume.

Training age also is relevant within the context of the chosen activity. Consider the case of two 12-year-old girls who are interested in trying out for a soccer team for the first time. If the first child participated consistently in daily physical education, outdoor free-play activities, and after-school gymnastics lessons during early childhood (approximately aged 7 to 8 years), she would have a different training age and subsequent level of general physical preparation than the second child who played 2 years of basketball at age 8 and 9 years and remained sedentary for several years thereafter. In this same light, is there a difference between a "good" training age and a "bad" training age? That is, a child who has participated in unsupervised "training" for 2 years is not necessarily better equipped than a child who has participated in age-appropriate, progressive, and supervised training for 12 months.

Because of the differing demands of available sport choices, it is recommended that aspiring young athletes engage in a variety of sports and physical activities to improve motor skill performance, enhance joint mobility and stability, and increase strength and power while gaining confidence in their abilities to be physically active and play sport. An important consideration in regard to the health and well-being of young athletes is to provide exposure to various activities whereby generic pattern recognition, hand-eye coordination, and decision-making skills

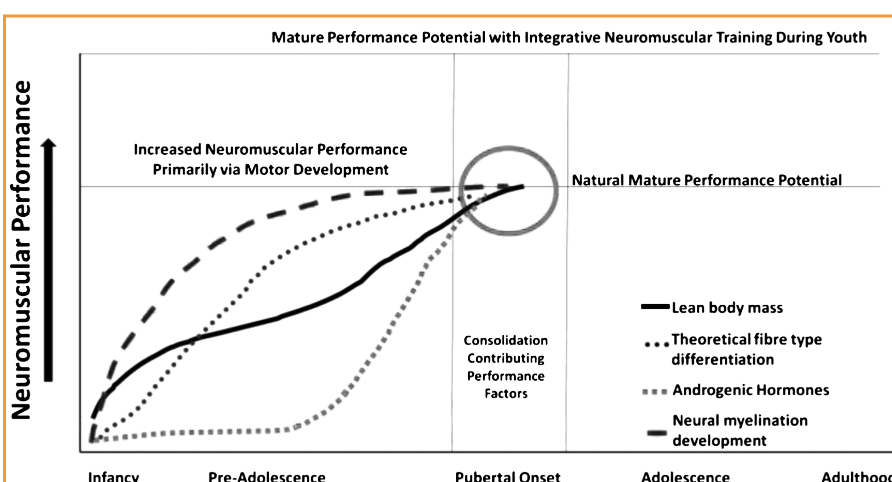


Figure 3. In the youth, there are several factors that contribute to motor control and strength expression. In children, motor control and strength may be less related to hypertrophy and more likely associated with neural development. It is proposed that integrative neuromuscular training focused on skill-related fitness (*e.g.,* agility, reaction time, coordination, power, speed, and balance) can maximize neural development during preadolescence and optimally prepare the youth to capitalize on the consolidated factors that contribute to motor performance after the onset of puberty. (Reprinted from: Kraemer WJ, Fry AC, Frykman PN, Conroy B, Hoffman J. Resistance training and youth. *Pediatric Exercise Science* 1989; 1:336–350 and from: Myer GD, Faigenbaum AD, Ford KR, Best TM, Bergeron MF, Hewett TE. When to initiate integrative neuromuscular training to reduce sports-related injuries and enhance health in youth? *Current Sports Medicine Reports* 2011; 10:157–166. Used with permission.)

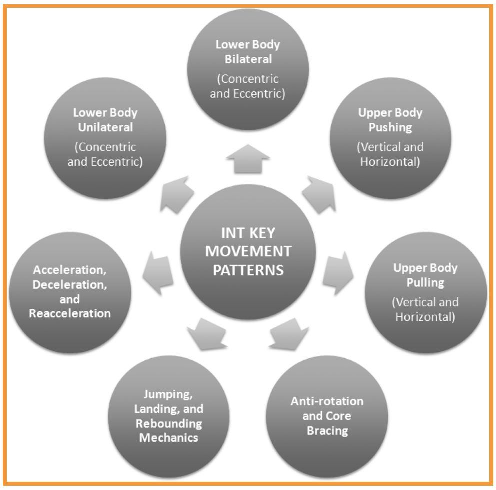


Figure 4. The key movement patterns that should be the cornerstone and focus of integrative neuromuscular training protocols.

can be tested and developed (3). This has important implications for the youth because early specialization has been linked previously to increased injury risk in young athletes (10). Research suggests that a cumulative exposure to a breadth of sporting experiences may indeed result in selective transfer of pattern recall skills and facilitation of expert performance (2).

Because the relative magnitude of forces from well-designed and INT programs typically are less than those from sport activities, there is little evidence to suggest that safety would be a limiting factor for the initiation of supervised INT with children. In many cases, children are able to learn basic movement patterns, such as squatting, pushing, pulling, hip hinging, core bracing, hopping, and jumping, and progress to more complex movements over time. The limiting factor is not their chronological or biological age, but rather the amount of time that they have been practicing these basic movements while gaining competence and confidence in their abilities to move. That is, their training age is an important factor, which influences their ability to perform simple and complex movement patterns with energy, vigor, and confidence. The importance of increasing a child's training age cannot be underestimated because it truly sets the stage for further physical development in later adolescence (31). Conversely, adolescents who do not develop training age in younger years will have more difficulty mastering FMS in their postpubertal and teenaged years.

The following section will discuss the physical changes that school-aged youth undergo that make them ideally suited to enhancing their FMS and general preparedness for sports. If young athletes begin to develop efficient movement patterns and continue to improve their muscle strength before adolescence, they will be better prepared for more advanced training and skill mastery because of their advanced training age (Fig. 2). Conversely, adolescents who have not been exposed to environments that enrich their motor skill development early in life will be ill prepared for advanced training because of their limited training experience and, consequently, will need to initiate INT with basic skills and exercises.

Although it is beyond the scope of the current report to outline the multiple variations of training exercises and protocols for various training ages, it should be noted that key INT movement patterns highlighted in Figure 3 will be included for youth of all training ages (12,30). However, relative to training age, there would be a difference in terms of overall focus on development of the skill within a training session. For example, for an adolescent with a training age of 0, the training session could include 70% FMS and 30% resistance training. Conversely, for an adolescent with a training age of 8+, these relative percentages of training focus could be reversed. Training that focuses on FMS is not only used with the younger training ages, but there is a need for greater emphasis on developing basic skills in the youth with less training experience. Fitness professionals must be sensitive to interindividual differences in physical development and fitness abilities between the youth of the same age, and training programs should be consistent with the needs, interests, and abilities of each participant.

Differential Programming for Youth Based on Training Age

If a child has engaged in appropriate training relative to his or her chosen activity, before and during maturation, he or she will be poised to capitalize on the many combinatory and consolidating factors that support motor skill performance during his or her postpubertal training years (Fig. 4). The postpubertal phase of development offers a unique opportunity for adolescents to benefit from significant neuromuscular adaptations, driven primarily via increases in testosterone, growth hormone, and insulin-like growth factor (37). Irrespective of the rate of maturation (*i.e.,* early, normal, or late), the alterations in hormonal profile associated with this stage of development will at some point lead to rapid developments in the musculoskeletal system. In addition to continued neural adaptation, the postpubertal phase also will induce alterations to muscle cross-sectional area (62), fiber pennation (6), and stiffness (28). There also will be natural adaptation to tendons, with research indicating that size (27), elasticity (29), and stiffness (66) increase throughout a child's development. In addition, adolescents typically will experience further increases in bone mineral density during this period (64). Collectively, these adaptations lead to rapid gains in overall body mass, with the greatest rate of change termed "peak weight velocity" (PWV), which occurs approximately 12 months after the growth spurt (Fig. 4) (8).

It is imperative that, at the postpubertal stage of development, adolescents continue to participate in structured INT programs to

TABLE 1: Example of a Whole-Body Session for an Adolescent With a Training Age of 0 Years

Session Phase	Exercise	INT Key Movement Pattern	Volume (sets × reps)	Intensity (% 1 RM)	Rest, min
Warm-up (FMS)	Foam roller complex	Whole-body myofascial release therapy	2 × 10 (each site)	N/A	1
	KB squat with deficit	Thoracic extension and hip mobilization	2 × 8	BW	1
	Split squats	Lower body unilateral (and gluteal activation)	2 × 6 (each leg)	BW	1
	Low box jump	Jumping, landing, and rebounding mechanics	2 × 6	BW	1
	Scapula push-ups	Scapula retraction	2 × 8	BW	1
	Monster band push press	Upper body pushing (vertical)	2 × 8	Light band	1
	Monster band pull downs	Upper body pulling (vertical)	2 × 8	Light band	1
	Plank variations	Antirotation and core bracing	2 × 30 s	BW	1
Main (resistance)	OH squat	Lower body bilateral	3 × 6	Wooden dowel or junior barbell	2
	Elevated press-ups	Upper body pushing (horizontal)	3 × 8	BW	2
	TRX supine pull-ups	Upper body pulling (horizontal)	3 × 8	BW	2
Auxiliary exercises	Stretching complex	N/A	2 × 20 s	N/A	1

reduce injury risk (7,44,59,65), enhance performance (44), and increase the likelihood of long-term physical activity adherence (60). INT programs are necessary to help reduce anterior cruciate ligament injury risk in postpubertal females, as they learn to perform with increased body mass and, of significance, a heightened knee valgus "collapse" mechanism (43). Specifically, postpubertal INT programs should focus primarily on FMS maintenance to ensure that motor coordination patterns learned during the prepubertal and pubertal phases have not been affected negatively as a result of the growth spurt. However, muscular strength is central to the successful execution of FMS. Resistance training should be the cornerstone of the INT program to build on existing strength levels and to take advantage of the increased hypertrophic environment within the muscle associated with the postpubertal stage of development (31,33).

During the postpubertal stage, it should be noted that the adolescent youth also may experience significant psychosocial changes, which negatively may affect their exercise adherence, such as motivation, self-perception, and confidence. For example, it has been stated previously that between 13 and 18 years of age, adolescents transition from a reliance on externally sourced feedback to greater use of self-referenced judgment of ability (25). Therefore, when working with postpubertal youth, it is essential that all training sessions attempt to foster a task-mastery motivational climate, encourage self-determined motivation, provide an adequate level of challenge, and enhance confidence (51,54,58). Such an approach will differ from those used when working with younger populations. Understanding these factors is important because they previously have been associated with dropout in youth sports (18). The use of social support systems (50), age-appropriate mental skill training (22), and ensuring that adolescents maintain a sense of peer friendship (57) are strategies that the qualified professional can implement to maximize enjoyment and help promote long-term participation in physical activity.

No Prior Engagement in INT During Prepubertal and Pubertal Phases (Training Age: 0)

It should be noted that the INT prescription should not be age determined but rather age related and primarily based on the training age of the young athlete. More specifically, INT should be based on training experience, biological status, motor skill competency, psychosocial maturity, and existing strength levels (30,31,33). Therefore, irrespective of chronological age, for postpubertal youth who have not participated in earlier INT programs, initial focus should be directed toward developing appropriate FMS in addition to developing base levels of muscular strength (Fig. 3). It should be noted that initiation of INT emphasizes each of the primary movements to be instituted for an adolescent with training age of 0 (Table 1). Although fundamental movements are consistent across training age and independent of chronological age, the youth who participate in INT-based programming early in life may be more equipped for the advanced programming indicated with increased training age (40,41).

Sedentary lifestyles and a failure to participate in INT programs before and around the onset of puberty will typically

TABLE 2: **Example of a Lower Body Session for an Adolescent With a Training Age of 8+ Years**

Session Phase	Exercise	INT Key Movement Pattern	Volume (sets × reps)	Intensity (% 1 RM)	Rest, min
Warm-up (FMS)	Foam roller complex	Lower body myofascial release therapy	2 × 10 (each site)	N/A	1
	Mini-band walks	Gluteal activation	2 × 10 (each leg)	N/A	1
	Clam shells	Gluteal activation	2 × 8 (each leg)	N/A	1
	Drop jumps (30 cm)	Jumping, landing, rebounding mechanics	3 × 3	BW	1–2
Main (Resistance)	Power clean	Lower body bilateral (CON)	3 × 4	80	2–3
	Back squat	Lower body bilateral (ECC/CON)	4 × 5	85	2–3
	Lunge	Lower body unilateral	3 × 6 (each leg)	85	2–3
Auxiliary exercises	Romanian dead lift	Lower body bilateral (ECC)	3 × 5	85	2–3

lead to poor posture, poor movement mechanics, and insufficient levels of muscular strength that do not reach the expected adult potential (Fig. 2). The lack of motor skill development associated with children who are not exposed to either INT or sport participation can foster reduced motor skill development relative to the youth of past. Sedentary youth who have a low training age initially will need to focus on FMS development that incorporates basic forms of locomotion, manipulation, and stabilization (35). In addition, a well-designed INT program also should enhance muscular strength expression within other key movement patterns (Fig. 3). Having the ability to express muscular force safely within the spectrum of movement competencies proposed in Figure 3 will provide the best opportunity for a child or adolescent to participate safely and effectively in a range of physical activities and allow them to tolerate the unpredictable impact forces commonly experienced in high-action sport activities. For those individuals who wish to participate in organized competitive sport, appropriate physical conditioning that includes muscle strengthening and FMS development will help reduce the potential for athletic injuries (63) and form the foundation for more advanced complex training modes, such as weightlifting (31,33) and advanced plyometrics (32).

Prior Engagement in INT During Prepubertal and Pubertal Phases (Training Age: 8+)

On the proviso that children participate in INT programs before and during puberty, the postpubertal phase offers a unique opportunity to build on existing levels of health- and skill-related fitness. Because of the earlier mastery of FMS and development of base levels of muscular strength, these individuals can be exposed to more intensive bouts of physical activity, with the knowledge that the inherent movement patterns are sufficiently robust to tolerate greater internal and external loads. However, a stipulation to this philosophy is that FMS should be revisited routinely irrespective of training history to avoid the manifestation of technical deficiencies over time (31). For example, it has been suggested that when prescribing agility training sessions,

TABLE 3: **Example of an Upper Body Session for an Adolescent With a Training Age of 8+ Years**

Session Phase	Exercise	INT Key Movement Pattern	Volume (sets × reps)	Intensity (% 1 RM)	Rest, s
Warm-up (FMS)	Foam roller complex	Upper body myofascial release therapy	2 × 10 (each site)	N/A	1
	Y, T, W, Ls	Scapula retraction	5 × 1	N/A	1
	Sitting t-spine rotations	Thoracic spine mobilization	3 × 4 (each side)	N/A	1
Main (resistance)	Bench pull	Upper body pulling (horizontal)	4 × 5	85	2–3
	DB bench press	Upper body pushing (horizontal)	4 × 5	85	2–3
	WG pull-ups	Upper body pulling (vertical)	3 × 6	80	2–3
	Snatch press	Upper body pushing (vertical)	3 × 6	80	2–3
Auxiliary exercises	SA bar rotations	Antirotation and core bracing	3 × 6 (each side)	80	2–3

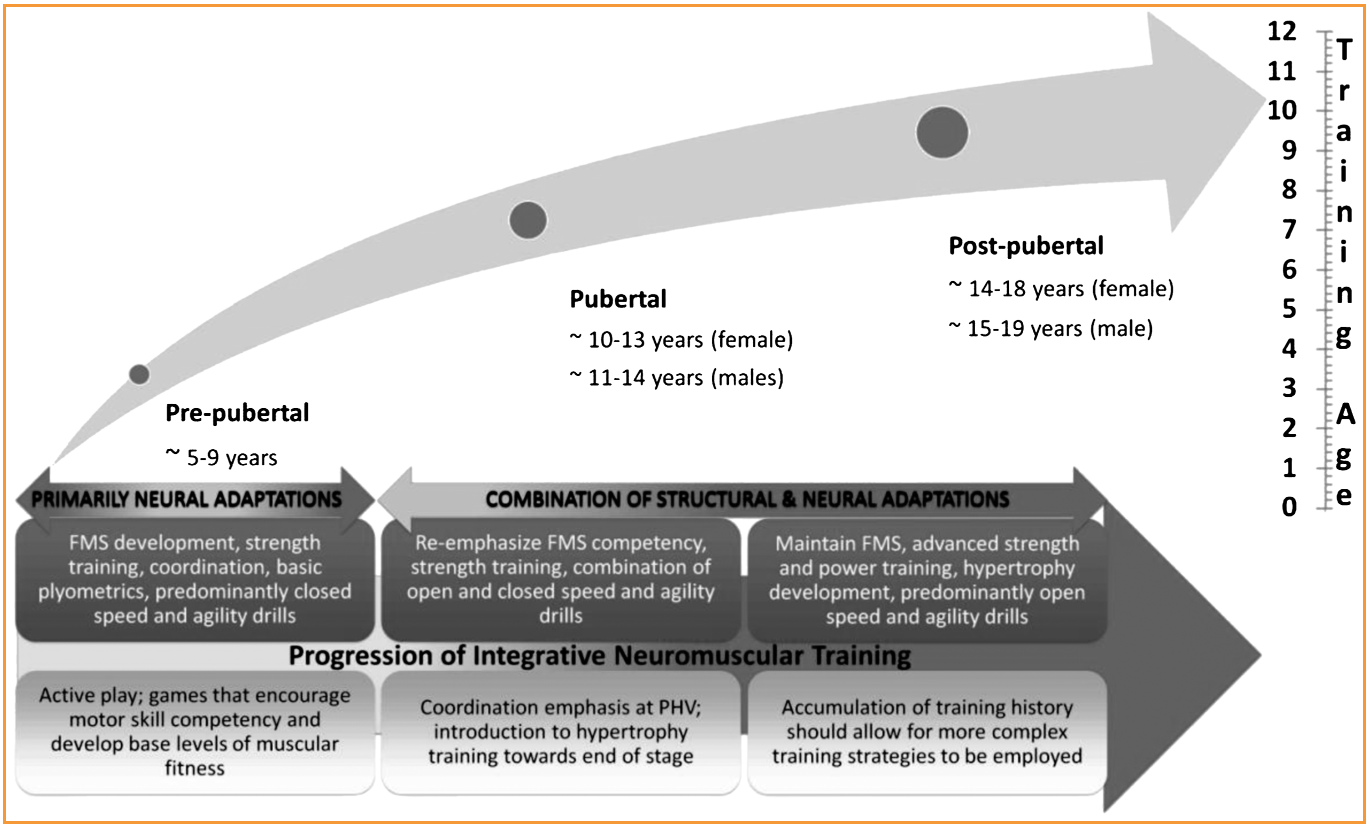
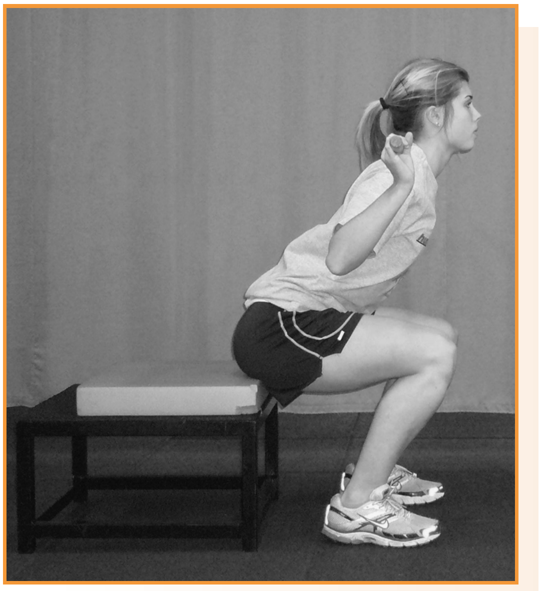


Figure 5. Graphical representation of the theoretical potential to increase training age by starting early in youth. Note that the recommended content is provided for each stage of maturation; however, as with any long-term development, there must be flexibility to ensure that programming is commensurate with the individual's training age.

qualified physical education teachers and youth coaches initially should prioritize FMS development and predominantly preplanned agility tasks during prepuberty (31,33). As the child enters puberty, the training emphasis should shift to a greater use of reactive agility drills while maintaining FMS competency, albeit for a smaller amount of time within a training session.



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Appropriately prescribed training in addition to the acute hormonal changes experienced during this phase of development will enable individuals to realize greater adaptations (both neural and architectural) to the neuromuscular system (Figs. 3, 5). Collectively, these changes will enable youth with an appropriate training age to generate greater overall force that consequently will enhance the performance of motor skills, such as sprinting (53) and jumping (34). In addition to traditional resistance training exercises (squatting, dead lifting, pressing, and pulling), weightlifting movements (clean and jerk, snatch, and their derivatives) and advanced plyometrics serve as safe and effective training methods for postpubertal youth to develop muscular strength and power. However, it is essential that those responsible for instructing weightlifting movements and advanced plyometrics to school-aged youth possess sufficient practical experience teaching these exercises to children and adolescents, a recognized professional certification, and a level of knowledge commensurate with a college degree in exercise science or physical education. Although less experienced fitness professionals can assist in the organization of youth programs, it is unlikely that they will be able to provide the level of instruction that is needed for more advanced INT, which may include weightlifting movements and more complex plyometric drills.

CONCLUSIONS

The cornerstone of INT is training age-appropriate education and instruction by qualified professionals who understand the principles of pediatric exercise science and the concept of training age. The initiation of INT early in youth can help increase training age that is vital for children and adolescents whose motor capabilities are highly "plastic" and responsive to training. Research demonstrates that significant amenable benefits can be gained from training age-appropriate interventions. Although an in-depth analysis of key training variables involved in successful youth INT programs is outside the scope of the current article, readers are directed to recent position statements from leading health and fitness organizations (12,30). Because of the growing interest in youth fitness and pediatric exercise, qualified fitness professionals are in an inimitable position to help children master FMS, improve movement mechanics, and gain confidence in their abilities to be physically active.

Due to space constraints, the complete list of references will appear online at [http://links.lww.com/FIT/A12].

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CONDENSED VERSION AND BOTTOM LINE

Recent trends indicate that widespread participation in organized youth sports is occurring at younger ages. With the increased involvement in competitive youth sport activities, there is growing interest from parents, clinicians, coaches, and teachers regarding the optimal age to encourage and integrate more specialized physical training into youth physical development programs. This review synthesizes the latest literature regarding the design and implementation of integrative neuromuscular training for school-aged youth. In addition, the concept of "training age" and its associated reductions in sport-related injury risk and improvements in motor skill development will be discussed to support participation in a variety of physical activities as an ongoing lifestyle choice.