



Pediatric Physical Activity

Exercise is sports medicine in youth: Integrative neuromuscular training to optimize motor development and reduce risk of sports related injury

El ejercicio es medicina deportiva en jóvenes: entrenamiento neuromuscular integrado para optimizar el desarrollo motor y reducir el riesgo en las lesiones deportivas

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ABSTRACT

Regular participation in organized youth sports does not ensure adequate exposure to skill- and health-related fitness activities, and sport training without preparatory conditioning does not appear to reduce risk of injury in young athletes. Current evidence indicates the widespread increased participation in organized youth sports is resulting from participation at younger ages. Concomitant with the increased participation without adequate preparatory condition is a surge of sports related injuries in our younger populations. Emergent research recommendations now promote motor

development, muscle strengthening and bone building activities for youth aged 6 and older. These recommendation along with increased involvement in competitive sport activities at younger ages, have influenced increased interest from parents, clinicians, coaches and teachers regarding the optimal age to encourage and integrate more specialized physical training into youth development programs to enhance physical fitness and reduce the risk of sports related injury. This review synthesizes the latest literature and expert opinion regarding when to initiate neuromuscular conditioning in youth and presents a how to integrative neuromuscular training conceptual model that could maximize the potential health-related benefits for children by reducing sports-related injury risk and encouraging lifelong regular physical activity.

Key words: neuromuscular, trining, injurys, youth people.

RESUMEN

En jóvenes, la práctica deportiva habitual no garantiza que estos adquieran una formación motora adecuada a sus necesidades, además la práctica de algún deporte de por sí, sin que existe una preparación condicional previa no parece reducir el riesgo de lesiones en los jóvenes deportistas. Las evidencias científicas actuales indican que el incremento de la práctica deportiva en niños y jóvenes sin la debida preparación condicional conduce a un aumento de la incidencia de lesiones en los jóvenes deportistas. Las nuevas investigaciones nos recomiendan promover el desarrollo de las habilidades motrices básicas, mejorar la fuerza muscular y la actividad ósea desde los 6 años en adelante. Esta recomendación junto con el aumento de la actividad competitiva en edades infantiles ha despertado el interés de los padres, médicos, entrenadores y profesores para diseñar programas de acondicionamiento destinados a mejorar el rendimiento físico y reducir la incidencia de lesiones. En esta revisión, se analizan las últimas publicaciones y la opinión de los expertos acerca de cuál debe ser el periodo más adecuado para iniciar a los jóvenes en un programa de acondicionamiento neuromuscular. Por otro lado, se presentará un modelo para introducir este tipo de programas para maximizar los posibles beneficios sobre la salud y reducir la incidencia de lesiones así como promover un estilo de vida activo en los niños y adolescentes.

Palabras clave: uromuscular, entrenamiento, lesiones, juvenes.

INTRODUCTION

There are an increasing number of children and adolescents who participate in recreational and interscholastic sports, yet recent data indicate that participation in organized sports activities does not ensure that youth meet the minimum recommended guidelines for moderate to vigorous physical activity (MVPA). (United States Department of Health and Human Services 2008; Leek, Carlson et al. 2010; Pate and O'Neill, 2010) While motor competence is associated with all health-related fitness related measures (i.e., aerobic fitness, muscle strength, muscle endurance, flexibility and body composition), pedometer measured physical activity appears to be only related to aerobic fitness. Moreover, increased participation in activities designed to enhance skill-related physical fitness (i.e., agility, balance, coordination, reaction time, and power) during childhood and adolescence may provide an optimal mechanism for enhancing physical fitness during adulthood. (Barnett, Van Beurden et al. 2009; Stodden, Langendorfer et al. 2009) Unfortunately, during the past quarter decade when recommendations for

physical activity have focused on continuous aerobic based movement, there has been a measurable decrement in neuromuscular development and motor skill performance concomitant with an increase in BMI in youth aged 9-12 years. (United States Department of Health and Human Services 2008; Runhaar, Collard et al. 2010) This decline in physical activity may start even earlier in life in youth who are overweight during infancy. (Gillis, Kennedy et al. 2006)

While sport participation provides a mechanism for increased physical activity and motor development in youth through intermittent exercise that is typically more appealing than continuous aerobic-type activities, regular participation in organized youth sports does not ensure adequate exposure to skill- and health-related fitness activities. (Leek, Carlson et al. 2010) In addition, sport training without preparatory conditioning does not appear to reduce risk of injury in young athletes. (Hewett, Myer et al. 2005; Hewett, Myer et al. 2006) Current evidence indicates the widespread increased participation in organized youth sports is resulting

from participation at younger ages (e.g., 6-8 years). Concomitant with the increased participation without adequate preparatory condition is a surge of sports related injuries in our younger populations. Emergent evidence-based research recommendations now promote motor development, muscle strengthening and bone building activities that are focused on the development and mastery of fundamental movement techniques for youth aged 6 and older.(Faigenbaum and Myer 2010; Faigenbaum, Farrel et al. 2011; Myer, Faigenbaum et al. 2011; Myer, Faigenbaum et al. 2011) These recommendations along with increased involvement in competitive sport activities at younger ages have increased interest from parents, clinicians, coaches and teachers regarding the optimal age to encourage and integrate more specialized physical training into youth development programs and physical education classes to enhance physical fitness and help reduce the risk of sports related injury. This review synthesizes the latest literature and expert opinion regarding *when* to initiate neuromuscular conditioning in youth and presents a *how* to integrative training conceptual model that could maximize the potential health-related benefits for children by reducing sports-related injury risk and encouraging lifelong regular physical activity.

NATURE VS NUTURE -IS REDUCED MOTOR DEVELOPMENT DURING YOUTH MODIFIABLE?

In genetic epidemiology it is frequently observed that diseases such as sports related injury risk may cluster in families, but individual family members may express a common phenotypic expression. (Martin, Hugentobler et al. 2011; Razquin, Marti et al. 2010) Likewise, children may inherit sensitivity to the effects of deprived physical activity environments that can influence reduced motor development during youth.(Foschini, Araujo et al. 2010) In post pubertal adolescents multidisciplinary interventions that included periodized progression of resistance exercises was a key component related to improvement of health parameters examined in obese adolescents.(Foschini, Araujo et al. 2010) Multidisciplinary integrative training models provided to pre-adolescent children may enrich their motor learning environment during the window of consolidated factors.(Myer, Faigenbaum et al. 2011) Environments enriched with integrative training may not only help them overcome any genetic limitations(Cooper and Zubek 1958), but may also help them achieve a level of motor performance that is beyond their expected adult potential.(Myer, Faigenbaum et al. 2011)

While there is no single gene that codes for motor performance in children, there are nervous system limits that differentiate between each child's opportu-

nity to exploit critical maturational thresholds for the development of dynamic interceptive actions (i.e., physical acts for which the body or an implement must be moved into the right place at the right time in order to accomplish a task).(Rosengren, Geert et al. 2003; Davids and Baker 2007) Skill-related fitness may not be an innate functionality hardwired at conception or gestation. Rather, it is more likely to be an accumulation of developed skills driven by the interaction between genes and the environment. Although speculative, a child in a non-enriched environment which is deficient in opportunities to regularly engage in activities that enhance fundamental motor skills may suffer long-lasting detrimental effects on health and disease risk later in life (Figure 1). This view is supported by the recent work of Lopes et al. (2010) who found that 6-year-old children with low and average levels of motor coordination had lower levels of physical activity 5 years later compared with children with high motor coordination. (Lopes, Rodrigues et al. 2010) Furthermore, in a 10-year longitudinal study of 630 adolescents, the participants first became involved in organized youth sports clubs between the ages 6–10 years. (Kjonnixsen, Anderssen et al. 2009) Interestingly, those who reported becoming members of a sports team at an even earlier age were more physically active as adults than adolescents who initiated sports involvement at older ages. (Kjonnixsen, Anderssen et al. 2009) It has been proposed that the high degree of plasticity in neuromuscular development during pre-adolescence combined with appropriately timed implementation and progression of integrative neuromuscular training may allow for strengthened physical, mental, and social development that contributes favorably to their athleticism during adolescence. It is also possible that the improved motor competence developed through adolescence facilitates the establishment of desired behaviors and habits that may carry over into adulthood.(Kjonnixsen, Anderssen et al. 2009; Myer, Faigenbaum et al. 2011).

On the basis of motor skill learning, pre-adolescence may provide an “optimal” window to train and develop long-lasting fundamental movement skills in boys and girls.(Gallahue and Ozmun 2006; Lubans, Morgan et al. 2010) Following maturation, young adult's corticomotor plasticity and potential for learning dynamic interceptive actions may be strongly diminished.(Rosengren, Geert et al. 2003; Hands 2008; Rogasch, Dartnall et al. 2009) Youth who do not regularly participate in this type of neuromuscular training in physical education classes, recreation programs, and youth sport centers may never reach their true genetic potential during adulthood. We also propose that children who do not participate in motor development activities prior to and during maturation, will be at high risk

of sports related injury without preparatory development activities.

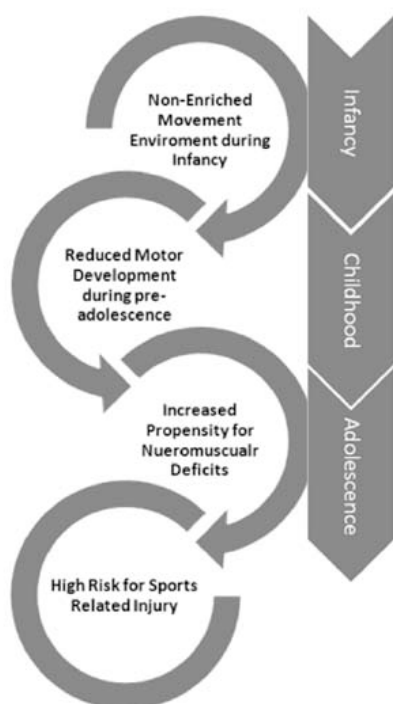


Figure 1. Potential consequences of non-enriched motor development environment during infancy and childhood.

Integrative training that is initiated prior to maturational onset (about age 12-14 years), may optimally prepare youth to exploit the consolidated factors that contribute to motor and power development during maturation. (Kraemer, Fleck et al. 1989; Myer, Faigenbaum et al. 2011) Integrative training is vital for healthy youth whose cognitive and motor capabilities are highly “plastic” and amenable to age-appropriate interventions, and may be even more critical for pre-adolescent youth with a decreased genetic potential for motor development. (Hands 2008; Ploughman 2008) Following maturation, corticomotor plasticity and potential for learning dynamic interceptive actions (actions for which the body, or an implement, must be moved into the right place at the right time in order to accomplish a task) may be diminished or even lost. (Hands 2008; Rogasch, Dartnall et al. 2009; Rosengren, Geert et al. 2003).

EXERCISE IS SPORTS MEDICINE: IS 60 MINUTES OF CONTINUOUS EXERCISE AN OPTIMAL PRESCRIPTION IN YOUTH?

During the past quarter decade when recommendations for physical activity have focused on continuous

aerobic based movement, there has been a measurable decrement in neuromuscular development and motor skill performance concomitant with an increase in BMI in youth aged 9-12 years. (United States Department of Health and Human Services 2008; Runhaar, Collard et al. 2010) Thus, the current focus on physical activity promotion in youth (i.e. at least 60 minutes of MVPA / day) may be inadequate for youth who need to develop motor skill that will support both health- and skill-related fitness components needed a healthy adulthood. (Hands, Larkin et al. 2009). Children with reduced motor skill competence are less able and willing to participate in sports and recreational activities and often find prolonged periods of aerobic exercise to be boring or discomforting. In support of these observations, it has been reported that total body fat was inversely related to minutes of vigorous physical activity per day in both boys and girls. (Dencker, Thorsson et al. 2006)

Despite the potential health-related benefits of regular aerobic training, motor skill competence during childhood is associated with improved physical fitness measures later in life. (Barnett, Van Beurden et al. 2009; Hands, Larkin et al. 2009) Hands and colleagues demonstrated over a five year period that for each year of the study, the low motor skill competence groups performed worse on all fitness and motor performance measures as compared to the high motor skill competence groups. In addition, children with low motor competence demonstrated significantly worse performance in measures of cardiovascular endurance, sprint speed and balance. Thus, children who perform poorly on motor performance tests or had low levels of fitness were unlikely to achieve similar levels of performance demonstrated by their age-matched peers who had higher levels of both health and skill-related fitness. (Hands 2008) A recent report indicated that objectively measured spontaneous physical activity can be induced in healthy children with a structured whole body intermittent integrative training programs. (Eiholzer, Meinhardt et al. 2010).

OPTIMAL EXERCISE FOR MEDICINE: INTEGRATIVE TRAINING INTO PREVENT MOTOR DEVELOPMENT DELAY IN YOUTH

Unlike general exercise recommendations for youth which typically refer to the accumulation of at least 60 minutes of MVPA on most days of the week, integrative fitness training refers to the performance of specific strength and conditioning activities that are purposely prescribed to enhance both health and skill-related components of physical fitness. (Myer, Faigenbaum et al. 2011). Rather than prolonged periods of aerobic exercise which is less appealing for children, recent findings indicate that integrative neuro-

muscular training which incorporates intermittent-type activities into a well-designed plan may offer more effective health and fitness value to aspiring young athletes. (Hewett, Myer et al. 2005; Hewett, Myer et al. 2006; Lubans, Morgan et al. 2010; Myer, Chu et al. 2008; Myer, Ford et al. 2005; Myer, Ford et al. 2006; Myer, Ford et al. 2006; Myer, Faigenbaum et al. 2011) Integrative neuromuscular training is characterized by short bursts of physical activity interspersed with periodic brief rest periods. (Myer, Faigenbaum et al. 2011; Myer, Faigenbaum et al. 2011) The intermittent rather than continuous nature of integrative neuromuscular training is more consistent with how youth move and play. (Bailey, Olson et al. 1995) It also includes a variety of training modalities which are sensibly prescribed and progressed over time. We suggest that integrative neuromuscular training initiated during pre-adolescence and maintained throughout adolescence will maximize the potential to achieve optimal adulthood motor capacity and reduce the risk of sports related injury. (Behringer, Vom Heede et al. 2011; Faigenbaum, Farrel et al. 2011; Myer, Faigenbaum et al. 2011; Myer, Faigenbaum et al. 2011).

The addition of integrative neuromuscular training to the total exercise dose of young athletes (i.e., sports practice, sports competition, and free play) should be carefully considered, as this could contribute to the chronic repetitive stress placed on developing musculoskeletal systems. The risk of an overuse injury increases if the intensity, volume or frequency of training or competition greatly exceeds the ability of the participants to tolerate the load, perform technically sound movements, or to sufficiently recover from prior activity bouts. (Bergeron 2009; Bergeron, Laird et al. 2009; Brenner 2007) An effective approach could be to integrate resistance, power and speed training into a progressive program in which the volume and intensity of training periodically change throughout the year (i.e., periodization). The systematic structuring of program variables, along with sufficient individual effort, qualified instruction and adequate recovery are key interrelated determinants of effective progressive integrative neuromuscular training. Adequate recovery between challenging training sessions seems to be overlooked in many youth conditioning programs that primarily focus on overload and progression. Safe and effective training of athletes at any age involves balancing the demands of training with the need for recovery to minimize injury risk and achieve training adaptation goals. This is particularly important for young athletes who represent different sports teams or participate in extracurricular sport activities at private training centers and in the community.

INTEGRATIVE NEUROMUSCULAR TRAINING DURING PRE-ADOLESCENCE TO REDUCE RISK OF SPORTS-RELATED INJURIES IN YOUTH – IS IT EFFECTIVE?

While the total elimination of sports-related injuries in youth is an unrealistic goal, appropriately designed and sensibly progressed integrative neuromuscular training programs may help to reduce the likelihood of sports-related injuries in young athletes. (Faigenbaum and Myer, 2010; Hewett, Ford et al. 2006; Hewett, Myer et al. 2005) By addressing the risk factors associated with certain youth sport injuries (e.g., low fitness level, muscle imbalances and errors in training), acute and overuse injuries could be reduced by 15 to 50%. (Micheli 2006; Valovich McLeod, Decoster et al. 2011) Lehnhard and colleagues significantly reduced injury rates with the addition of a strength training regimen in male soccer players. (Lehnhard, Lehnhard et al. 1996) Cahill and Griffith incorporated resistance training into preseason conditioning for adolescent football teams and, over four competitive seasons, reported a reduction in overall knee injuries including the incidence of knee injuries that required surgery. (Cahill and Griffith, 1978) Likewise, Emery and Meeuwisse found that integrated neuromuscular training was protective of all injuries including acute onset injury in young soccer players. (Emery and Meeuwisse, 2010) Notably, protocols that incorporate resistance training into pre-season and in-season conditioning programs reduce anterior cruciate ligament (ACL) injury risk factors and ACL injuries incidence in female athletes. (Hewett, Ford et al. 2006; Hewett, Myer et al. 2005;). Although only a small minority of young athletes participate in integrative neuromuscular conditioning programs prior to sports participation, (Brooks, Schiff et al. 2007) these data indicate that such multi-faceted conditioning programs may indeed reduce sports-related injuries in adolescents and that similar results would be observed in pre-adolescent populations if such programs were applied. (DiStefano, Padua et al. 2010; Gilchrist, Mandelbaum et al. 2008; Hewett, Lindenfeld et al. 1999).

HOW TO INITIATE INTEGRATIVE NEUROMUSCULAR TRAINING DURING PRE-ADOLESCENCE

While integrative fitness training refers to the performance of, specific strength and conditioning activities that are purposely prescribed to enhance both health and skill-related components of physical fitness. (Myer, Faigenbaum et al. 2011). High-intensity training should only be performed two to three times per week on nonconsecutive days to allow time for sufficient recovery between training sessions. (Faigenbaum, Kraemer

et al. 2009) When young athletes participate in strength and conditioning activities more than three days per week, factors such as the overall training volume, training intensity, exercise selection, and nutritional intake should be carefully considered as these factors directly influence the ability to recover from and appropriately adapt to the training program. Youth coaches should monitor each child's progress and should be cognizant of the signs and symptoms of overtraining which include lingering muscle soreness, unexpected performance decrements and notable changes in sleep habits, appetite and mood. Of note, youth coaches should realize that some children with relatively immature musculoskeletal systems cannot safely tolerate the same exercise dose that many of their teammates can endure. (Brenner 2007; Winsley and Matos, 2011).

The prescribed exercises, sets and repetitions for an effective integrative neuromuscular exercise program should be individualized and attainable for each athlete. Initial volume selection should be low to allow the athlete to learn how to perform each exercise with proper technique. (Faigenbaum, Farrel et al. 2011; Myer, Faigenbaum et al. 2011; Myer, Faigenbaum et al. 2011) Volume (or resistance, when applicable) should be increased after the athlete can properly perform the exercise at the prescribed volume and intensity. The professionals who supervise young athletes should be skilled in recognizing proper technique and should provide constructive feedback during the learning and development process, especially when improper technique increases injury risk. Once the young athlete becomes proficient with all exercises within a progression phase, s/he can advance to the next successive phase. Young athletes should participate periodically in less intense training (LIT) sessions to encourage and reinforce learning of specific movement patterns. (Faigenbaum and Mcfarland, 2006) Accordingly, high intensity and/or high volume training sessions should be regularly balanced with LIT sessions, as well as other recovery strategies to maximize training adaptations while minimizing the risk of overtraining. (Winsley and Matos, 2011).

A recent meta-analysis on youth resistance training indicates that improved muscular strength is dependent on adequate volume to provide sufficient adaptive stimulus. (Behringer, Vom Heede et al. 2010) Distefano and colleagues modified traditionally effective training programs previously used adolescents, (Hewett, Lindenfeld et al. 1999; Mandelbaum, Silvers et al. 2005; Myer, Ford et al. 2006) into a 9-week "integrated injury prevention program" for use as an additive training regimen during the warm-up period in young soccer player (10-12 years). The addition of integrative injury prevention training program into standard soccer tra-

ining influenced improvements in balance ability and vertical jump height in the young soccer players. (DiStefano, Padua et al. 2010) Clearly, participation in physical activity should not begin with competitive sport but should evolve out of well-rounded preparatory fitness conditioning that is sensibly progressed over time. With addition of integrative neuromuscular training into existing practice activities, coaches can be better equipped to ensure that youth will see greater gains in skill-related fitness and health with likely reductions in risk of sports related injury.

There is not one combination of exercises, sets and repetitions that has proven to optimize training adaptations; however, it appears that multi-faceted and integrative programs that increase muscle strength, enhance movement mechanics, and improve functional abilities appear to be the most effective strategy for reducing sports-related injuries in young athletes. Moreover, fundamental movement skills competency in children and adolescents can increase physical activity, improve cardiorespiratory fitness and enhance body composition (BMI z-score). (Lubans, Morgan et al. 2010) Although there are many approaches to potentially reduce youth sports-related injuries (e.g., coaching education, safe equipment, proper nutrition), enhancing physical fitness as a preventative health measure is considered a cornerstone of multi-component programs for school-age youth. This is an important consideration for health care providers who often perform pre-participation physical examinations in order to assess a young athlete's readiness for sport (Hewett, Myer et al. 2006). In addition to the medical examination (including a musculoskeletal assessment), health care providers should inquire about a patient's participation in physical activities over the past few months.

Proper education and instruction are paramount for safe, effective and enjoyable integrative neuromuscular training (Figure 2). However, initiation of integrative neuromuscular training in during pre-adolescence must also be challenging and enjoyable to keep the children interested and motivated in continuing participation. (Faigenbaum, Farrell et al. 2009; Faigenbaum, Kraemer et al. 2009) Age-appropriate education and qualified instruction are required to successfully integrate different components related to the mastery of fundamental movements, program variation, exercise progression and structured recovery. Because a growing number of school-age youth are exposed to strength and conditioning activities in physical education classes and community recreational and sports training programs, (Faigenbaum, Kraemer et al. 2009; Lee, Burgeson et al. 2007) the importance of qualified and enthusiastic instruction that is consistent with individual needs, goals and abilities is critical. Children

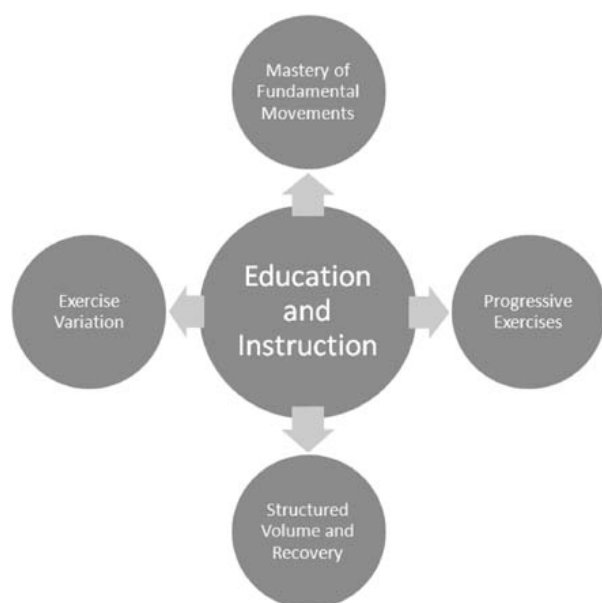


Figure 2. Education and Instruction are the key components for effective implementation of integrative neuromuscular training. Reprinted with permission from Myer GD, Faigenbaum AD, Chu DA, Falkel J, Ford KR, Best TM, Hewett TE. Integrative training for children and adolescents: techniques and practices for reducing sports-related injuries and enhancing athletic performance. *Phys Sportsmed.* Feb 2011;39(1):74-84. Copyright 2011 by JTE Multimedia.

and adolescents who participate in integrative neuromuscular training programs should be knowledgeable of the potential risks and concerns associated with exercise equipment (e.g., treadmills, weight machines, barbells) and should be aware of the potential risk of injury if they do not follow established training guidelines and safety procedures. Ultimately, education and

instruction will determine the levels of success that can be achieved within each component of an integrative neuromuscular training program (Figure 2).

SUMMARY AND CONCLUSIONS

Regular participation in organized youth sports does not ensure that youth are adequately exposed to fitness regimens and activities that sufficiently improve health and sports-specific fitness to minimize risk of injury and promote lifelong health and fitness. Accordingly, participation in organized physical activity programs should not begin with competitive sport, but should evolve out of regular participation in a well-rounded preparatory conditioning program. Integrative neuromuscular training programs that integrate a variety of fundamental movements designed to enhance both health and skill-related fitness may be most beneficial if initiated during pre-adolescence. Moreover, integrative neuromuscular training is more likely to have long-lasting effects if qualified professionals focus on the process of developing fundamental motor skills rather than the product of enhanced sports performance. Integrative neuromuscular training maintained throughout childhood and adolescence will likely improve movement biomechanics, minimize the risk of sports-related injury, and promote positive health outcomes during adulthood. With a understanding of the physical and psychosocial uniqueness of children, integrative neuromuscular training that is sensibly progressed over time and consistent with individual needs, goals and abilities can be integral to development and promotion of a health-oriented approach to lifelong physical activity.

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