CRONOS Pediatric Physical Activity

Integrative neuromuscular training for youth

Entrenamiento muscular integrado para jóvenes

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ABSTRACT
The positive effects of a multifaceted well design training which include neuromuscular exercises (jumping, throwing, balancing and resistance exercise) has been stated by several researchers. This type of activity has been found to positively affect selected measures of health- and skill-related fitness or specific sports related tasks and reduce the incidence of injury during training and competition. The primary goal of physical activity programs for youth must be to improve muscle strength and fundamental motor skill performance by performing a variety of exercises with progressive loads that are consistent with individual needs, goals and abilities.
This paper analyze the period of the life where the introduction of a well designed and supervised integrative neuromuscular program is necessary to support the process of growth and maturation, stimulate an active and healthy lifestyle and even enhance performance beyond the increment produced by normal growth.

Key Word: Integrative neuromuscular, resistance training, children.

RESUMEN
Los efectos positivos de un programa de entrenamiento multifacético, adecuadamente diseñado y supervisado que incluya como componentes fundamentales ejercicios de tipo neuromuscular (saltos, lanzamientos, ejercitaciones con equilibrio perturbado o ejercicios de fuerza, etc.) han sido documentados por numerosas investigaciones. Los benefi-

cios más destacables de estos programas de entrenamiento se producen sobre diversos marcadores de salud, habilidades motrices o en la realización de acciones deportivas específicas así como en la reducción de la incidencia de lesiones durante el entrenamiento y la competición. El objetivo principal de los programas de actividad física en niños y jóvenes debe ser mejorar los niveles de fuerza muscular y el dominio de las habilidades motrices básicas realizando una gran variedad de ejercicios con dificultad y sobrecargas progresivas que deben estar siempre programados en función de las necesidades individuales y nivel de rendimiento de cada sujeto. Este artículo analiza los periodos de la vida en donde es necesario introducir un programa de entrenamiento de tipo neuromuscular, adecuadamente diseñado y supervisado, para apoyar los procesos de maduración y crecimiento, estimular un modo de vida activo además de mejorar el rendimiento otorgando beneficios superiores a los que se pueden alcanzar por el normal crecimiento y desarrollo.

Palabras clave: Entrenamiento neuromuscular, entrenamiento de fuerza, jóvenes.

INTRODUCTION

During the childhood ages somatic and maturational features determine the type of effort expended during sports. It is possible that the lack of uniform criteria regarding to how to integrate physical conditioning program as an essential component for pre pubertal and adolescents athletes is one of the principal issues on which professionals should work in order to avoid common mistakes when designing training programs for youth.

This paper is focused on analyzing the potential risks and benefits of introducing a neuromuscular oriented training program in children and adolescents. In addition, we will analyze what could be the more appropriate period of training to introduce this type of program as a key component of physical education and youth sport programs.

PHYSICAL ACTIVITY DURING GROWTH AND DEVELOPMENT

According to Myer et al (2011b) the term "youth" refers to children (Tannerstages 1 and 2 of sexual maturation; approximately up to age 11 yr in girls and 13 yr in boys) and adolescents (Tanner stages 3 and 4 of sexual maturation; approximately ages 12 to 18 yr in girls and 14 to 18 yr in boys). The term preadolescent refers to boys and girls who have not yet developed secondary sex characteristics. Adolescence refers to the period of time between childhood and adulthood and includes girls aged 12 to 18 years and boys aged 14 to 18 years. Strength and conditioning (also called resistance training) is defined as a specialized method of training that involves the progressive use of a wide range of resistive loads, different movement velocities and a variety of training devices including weight machines, free weights (barbells and dumbbells), medicine balls, bands and body weight. This term should be distinguished from the competitive sports, of weightlifting and powerlifting (Myer et al., 2011b).

Many physiological changes related to growth and development occurs at a rapid rate during childhood and adolescence. It can be expected that healthy children and adolescents will show noticeable gains in height, weight, and measures of physical fitness during the developmental years even without participation in a structured strength and conditioning program. For example, muscular strength normally increases from childhood through the early adolescent years, at which time there is a marked acceleration in strength in boys and a general plateau in strength in girls (Malina et al., 2004). For this reason, some low volume and short-duration training program may not induce distinguishable gains from that obtained due to normal growth and development. This is an important consideration when evaluating research studies that failed to demonstrate a strength increase following a neuromuscular oriented conditioning program. Of note, throughout this stage of development there are critical periods of time during which youth seem to have a high sensitivity to physical training and neuromuscular conditioning (Viru et al., 1999). For example, children appear to be particularly sensitive to the development of motor function and abilities between 7 and 9 years of age just before to reach a peak high velocity (Viru et al., 1999). Although speculative, pediatric strength and conditioning programs that include exercises and activities that enhance motor skill performance emphasizing the neuromuscular type exercise will likely set the stage and allow the children to be better prepared to face the pubertal stage with the potential to reach a greater adaptability and more efficient functioning (Viru et al., 1999). This approach would provide even greater gains in strength and power during adulthood (Myer et al., 2011b).

In prepubescent children, their skeletal system has great mobility, their bones are long and elastic having an important growing activities specifically at the spine

level so it is very important in this stage together with specific coordinative task include exercise aimed to strengthen the core musculature (abdominal or back muscles). This type of exercise will help to improve the stability and the capability to control the motor skills task required during different type of sports (Mickle et al., 2011).

Figure 1 illustrates the rate of stature increase (cm per year) and the principal goals of integrating regularly neuromuscular type training along the lifespan. During the pre adolescents stage the goal of neuromuscular training for children must be to learn and practice as many fundamental motor skills as they are possible to learn (Lubans et al., 2010).

It is important to note that during the pubescence is easier to create an exercise over load that may induce overtraining. During this period, young boys and girls start to increase muscle strength and demonstrate a high capacity and responsiveness to respond to an increased training load but also their bone structure are less stable because are growing faster than in previous phase and can be injured easier due to applied excessive loads or training volume (Byrd et al., 2003) On the other hand physical activities through a multifaceted program that include resistance training exercise should start at prepuberal ages and should be maintained throughout the pubertal development to obtain a well developed bone structure. Starting physical activity prior to the pubertal growth spurt stimulates both bone and skeletal muscle hypertrophy to a greater degree than observed with normal growth in non physical active or sedentary children (Vicente-Rodriguez et al., 2004).

An understanding of the possible outcomes of strength and conditioning on youth will assist in the design of fitness programs that optimize training adaptations. If strength and conditioning programs are well-designed and of sufficient intensity, volume and duration, children and adolescents can significantly improve their muscular fitness above and beyond growth and development (Faigenbaum and Myer, 2010, Myer and Wall, 2006, Payne et al., 1997).

NEUROMUSCULAR TRAINING FOR YOUTH

The integrative neuromuscular training is a concept to apply a multifaceted type activity which incorporate general (fundamental movement) and specific (exercise targeted to motor control), strength and conditioning activities such a resistance dynamic stability, core focused strength, plyometric and agility that are designed to enhance health and skill related component of physical fitness (Myer et al., 2011b).

The cornerstone of Integrative neuromuscular training is appropriate education and instructor given by qualified professional who understand the fundamental principles of pediatric exercise since they have to

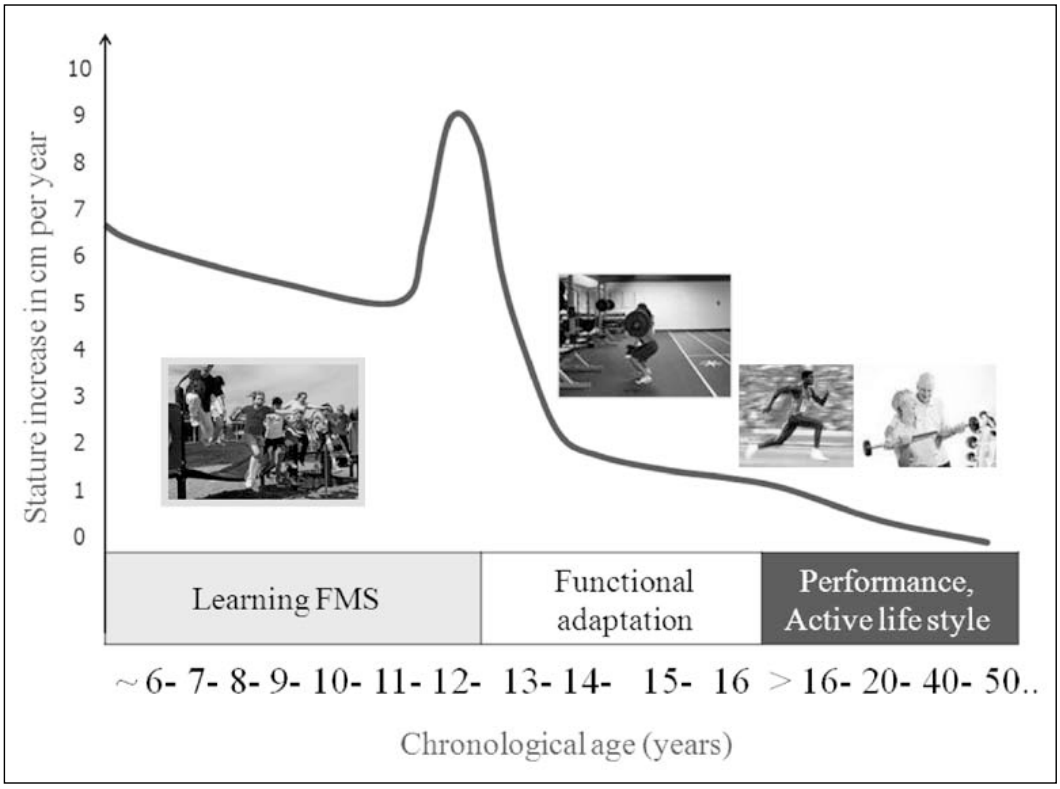

Figure 1. Goals of integrating an strength and conditioning program along lifespan.

consider and appreciate the physical and psychological requirement of children and adolescents (Myer et al., 2011b).

As we suggested before, between 6 to 8 years old is the period of life were the children are very sensitive to this type of training and show a great predisposition for learning and practicing fundamental motor skills. Once children learn basic motor tasks, they can progress to more advanced movements such as the squat, lunge or even weightlifting movements (e.g, modified cleans, pulls and presses). During this period the teacher or coach must emphasize appropriate lifting technique rather than the amount of the weight lifted which must based on each child's individual performance and technical abilities (Faigenbaum and Myer, 2009). Table 1 summarizes the principal goals of applying a neuromuscular training for youth.

poprotein cholesterol, glucose (Garcia-Artero et al., 2007) C-reactive protein (Ruiz et al., 2008), and insulin resistance (Benson et al., 2006) as well as other type of skeletal or postural disorders such as back pain (Bo Andersen et al., 2006), reduced mineral content (Vicente-Rodriguez et al., 2004). In addition some longitudinal studies revealed that levels of muscular strength during adolescence appear to track into adulthood (Mikkelsson et al., 2006).

Taken together, these findings support the idea that muscular strength may exert a positive effect on the health status in young people as well and highlight the importance of regularly and well designed training program for children and young that emphasize the neuromuscular type exercise and intermittent activities which reflect the nature of spontaneous activities in children (Castro-Piñero et al., 2009).

Table 1. Neuromuscular training goals for children and adolescents

1	Optimize growth and development (Behringer et al., 2010, Slining et al., 2010)
2	Acquire a great variety of motor skills (Lubans et al., 2010)
3	Enhance muscle strength and exercise technique (Faigenbaum and Myer, 2010)
4	Improve dynamic stability and postural control (Mickle et al., 2011)
5	Improve predisposition to do other physical activities (sports, games, etc) (Faigenbaum and Myer, 2010)
6	Stimulate anactive and healthy lifestyle (Slining et al., 2010)

POTENTIAL RISK AND BENEFITS ASSOCIATED TO NEUROMUSCULAR RESISTANCE TRAINING IN CHILDREN AND YOUNG

Little research has focused on the motor developmental consequences of an unhealthy behavior such as sedentary life style during pediatric ages. Childhood and adolescents in particular are very sensitive and vulnerable period of life where lack of physical activity could result in a vortex or cascade of untoward health behaviors and pathological processes such as obesity and metabolic disorders that can be hold later in life (Slining et al., 2010). Studies in developing countries provide evidence of motor developmental delays and deficits associated with under-nutrition (Eickmann et al., 2007) but few studies have examined motor developmental consequences associated with over-nutrition or a restrict motor development caused by a lack of an adequate physical activity during childhood.

Results from cross-sectional studies in children and adolescents have reported a negative relationship between muscular strength and cardiovascular disease risks factors such as triglycerides, total cholesterol, high-density lipoprotein cholesterol, low-density li-

Regarding the potential risk of implementing an integrative neuromuscular training program in youth, several studies have suggested that between 15% and 50% of the total reported sports injuries in children and young could be reduced with an good and adequately supervise neuromuscular conditioning training program that emphasized special movement technique such landing, throwing or jumping and strengthened the core musculature. Strengthening core muscle will help to increase the balance capabilities which is an important requirement to improve basic motor skills abilities (DiStefano et al., 2010). If the ability to balance is not mastered in the early years of life, it can potentially reduce the efficiency of performing more complicated movement skills, such as running and jumping, and may increase the likelihood of a child sustaining an injury during sports participation (Mickle et al., 2011). Table 2, summarized the benefits provided by a regularly well designed and supervised training program that contribute to reduce the injury rate in children during sports practice

A traditional concern regarding the risk of injury in children and adolescents is the possibility of damage to the developing skeleton of young lifters. Disturbed

Table 2 Benefits associated with a neuromuscular training program in children and young

1	Strengthenendon, ligaments and bones (Faigenbaum et al., 2009).
2	Improve balance and strength level between agonist and antagonists muscle groups (Faigenbaum et al., 1996)
3	Improve the capability to adapt and better withstand the load from sports practice and competition (Myer and Wall, 2006)

physeal growth as a result of injury can result in length discrepancy, angular deformity, or altered joint mechanics, and may cause significant long-term disability (Maffulli et al., 2010). Shanmigan and Maffulli (2008), Reported that the majority of sports related injury in children are produced during team, fighting or gymnastics. 43.8% of all injuries occur in the upper extremity, 34.5% in the lower extremity and 16% in the head, and peak at the age of 12 years old. Sprains, contusions and lacerations account for the majority of injuries. However these authors did not mention any type of injury produced during resistance training or weightlifting sports (Shanmugam and Maffulli, 2008).

The belief that lifting weight can be dangerous and alter the normal growth was based on the experimental studies carried out with animals but never has been confirmed in humans (Cañadel and De Pablos, 1988, Faigenbaum et al., 2009).

The latest scientific report agree to confirm that the majority of youth resistance training injuries are the result of accidents that are potentially preventable with increased supervision and stricter safety guidelines (Myer et al., 2009).

Table 3 summarizes the positive effects produced by a regularly well designed and supervised neuromuscular training program in youth.

et al., 2011b). The supposed success of this methodology is based on the adequate supervision, a progressively enhance of the motor capabilities and control of the safety measure during each training session. This type of program has shown to be effective not only for improving motor performance in children beyond the benefits due to the normal growth and development (Faigenbaum et al., 2009) but also to reduce the incidence of injury during training (Myer et al., 2011b) and competition (Koutures and Gregory, 2010). That is because the intermittent types activities which predominantly include neuromuscular type exercise should be included as a fundamental parts of physical conditioning programs (Myer et al., 2011a). However, until now we were unable to find long-term studies (>6 month) which analyzed the effects of this type of program on the motor performance in children and adolescents. Myer et al. (2005), showed positive effects to reduce the rate of injury and enhance motor performance in 53 basketball or volleyball young women player whose underwent a six weeks dynamic neuromuscular program which included jumping, changes in directions, balance exercise, etc (Myer et al., 2005). The same research groups have proposed that in order to improve the motor control, the recovery time between high intensity tasks and reduce the incidence of injury in

Table 3 General effects of neuromuscular training in children and adolescents

1	Strength increment is more proportional than body size (Behm et al., 2008)
2	Improve performance in specific sports tasks (soccer, football, tennis, baseball, rugby, etc..) (Faigenbaum et al., 2009)
3	Reduce the rate of injury during sports practice (Myer et al., 2011a)
4	Help to reduce the incidence of metabolic or musculoskeletal disorders (Falk, 1996, Faigenbaum and Myer, 2010)
5	Improve body composition and positively stimulate adequate growth and development (Faigenbaum et al., 2009)

INTEGRATION OF NEUROMUSCULAR RESISTANCE TRAINING IN CHILDREN ATHLETES

The positive effects of the integrative neuromuscular physical conditioning programs added with other more common sports practice have been recently proposed by several publications (Faigembaum and Naclerio, 2011, Faigenbaum et al., 2009, Myer et al., 2011a, Myer

young athletes, the integration of neuromuscular exercise as an essential component of the conditioning program is a very important issue to consider (Myer et al., 2008). However, adding 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 devel-

oping musculoskeletal system. In this regard, Koutures and Gregory (2010), suggest that during the warm-up phase a short volume but well designed exercise program which includes neuromuscular and intermittent training (table 4) could result in desired outcomes by enhancing performance and reducing the incidence of injuries in young athletes.

Table 4. Exercise recommended for including INT in a low-volume warm-up program.

1. Jogging, skipping, backward running, and carioca
2. Strengthening exercises: Lunges, squats, hamstring-strengthening exercises, and toe raises
3. Plyometrics exercises: Variety of hopping, jumping, and bounding drills
4. Agility exercises: Shuttle, diagonal running and changes directions

As we mentioned before, the success of this type of program will deepens on qualified instructors who have to be aware of the appropriate methodology and progression that is consistent with individual needs, goals and abilities (Koutures and Gregory, 2010, Lubans et al., 2010).

An effective approach may be to incorporate integrative neuromuscular training into a sports program or physical education class. Thus, resistance, power and speed exercises can be integrated into a progressive conditioning program in which the volume and intensity of training periodically change throughout the year (i.e., periodization). Periodization strategies will help to optimize training adaptations and reduce the likelihood of overtraining and burnout in youth (Caine et al., 2006)

Once the young athlete becomes proficient with basic exercises within a training phase, , the coach or teacher should modify the training program in order to keep the stimulus effective. By periodically varying the choice of exercise, training intensity, and training volume, training adaptations will be optimized. A recent meta-analysis on youth resistance training indicates that improved muscular strength is dependent on adequate volume to provide sufficient adaptive stimulus (Behringer et al., 2010).

Based on the above information we carried out a pilot study aimed to assess the viability of a periodized integrative neuromuscular training program (PINTP) in 59 children soccer player (7 to 8 years old). The program was applied twice a week in non consecutive days during 10 weeks (20 sessions in total). During the first 20 min of each training session the children underwent short volume well designed neuromuscular program involving 3 sets of 8 to 12 repetition of 6 different exercises such ruining, change directions, jumping and landing with two or one leg or even with light resistance provided by balls or vest weight (0.5 to 1kg), throwing medicine ball of different size and load, basic core and stable exercise (abdominals of holding different static position, etc.

In order to keep the high level of motivation and maintain the desired intensity, the exercises were gradually changed in accordance with the performance progress experimented by the children. At the end of the program more than 100 different type of exercise were used.

The preliminary results of this study showed that all the session was done within the 20 min time. Forty nine children (83%) completed more than 16 sessions (80%). Anyway all the children (100%) presents at any session completed all the exercise involved in the PINTP and always manifested to be motivated and interested on the tasks proposed by the coaches.

CONCLUSION

The primary goal of physical activity programs for children and adolescents should be to improve muscle strength and fundamental motor skill performance by performing a variety of exercises with progressive loads that are consistent with individual needs, goals and abilities. These types of training can be easily integrated during the warm up period or incorporated into physical education classes. This type of physical activity will not impair the technical progress in specific sports, but will likely enhance physical fitness reduce the incidence of sports-related injuries and stimulate a more active lifestyles later in life (Faigenbaum and Naclerio, Chap, 25, Panamericana, 2011).

REFERENCES

Behm, D. G., Faigenbaum, A. D., Falk, B. & Klentrou, P. (2008). Canadian Society for Exercise Physiology position paper: resistance training in children and adolescents. *Appl Physiol Nutr Metab*, 33, 547-61.

Behringer, M., Vom Heede, A., Yue, Z. & Mester, J. (2010). Effects of resistance training in children and adolescents: a meta-analysis. *Pediatrics, 126*, e1199-210.

Benson, A. C., Torode, M. E. & Singh, M. A. (2006). Muscular strength and cardiorespiratory fitness is associated with higher insulin sensitivity in children and adolescents. *Int J Pediatr Obes, 1*, 222-31.

Bo Andersen, L., Wedderkopp, N. & Leboeuf-Yde, C. (2006). Association between back pain and physical fitness in adolescents. *Spine, 31*, 1740-1744.

Byrd, R., Pierce, K., Rielly, L. & Brady, J. (2003). Young weightlifters' performance across time. *Sports Biomech.0, 2*, 133-134.

Caine, D., DiFiori, J. & Maffulli, N. (2006), Physeal injuries in children's and youth sports: reasons for concern? *Br J Sports Med, 40*, 749-760.

Cañadel, J. & De Pablos, J. (1988). *Lesiones del cartílago de crecimiento*, Salvat.

Castro-Piñero, J., González-Montesinos, J. L., Mora, J., Keating, X. D., Girela-Rejón, M. J., Sjöström, M. & Ruiz, J. R. (2009). Percentile values for muscular strength field tests in children aged 6 to 17 years: influence of weight status. *J Strength Cond Res, 23*, 2295-2310.

DiStefano, L. J., Padua, D. A., Blackburn, J. T., Garrett, W. E., Guskiewicz, K. M. & Marshall, S. W. (2010). Integrated injury prevention program improves balance and vertical jump height in children. *J. Strength Cond. Res., 24*, 332-342.

Eickmann, S. H., de Lira, P. I., Lima Mde, C., Coutinho, S. B., Teixeira Mde, L. & Ashworth, A. (2007). Breast feeding and mental and motor development at 12 months in a low-income population in northeast Brazil. *Paediatr Perinat Epidemiol, 21*, 129-37.

Faigembaum, A. & Naclerio, F. (2011). Prescripción Del Entrenamiento En Niños Y Adolescentes. Capitulo 25. IN NACLERIO, F. (Ed.) *Entrenamiento Deportivo: Fundamentos y aplicaciones en diferentes Deportes. Editorial Médica Panamericana.*387-402

Faigenbaum, A. (2006). Strength training in children and adolescents: Adaptation responses performce and safety aspects. In Agarrad, P., Madsen, K., Magnusson, P. & Bojsen-Moller, J. (Eds.).

Faigenbaum, A. D., Kraemer, W. J., Blimkie, C. J., Jeffreys, I., Micheli, L. J., Nitka, M. & Rowland, T. W. (2009). Youth resistance training: updated position statement paper from the national strength and conditioning association. *J Strength Cond Res, 23*, S60-79.

Faigenbaum, A. D., Kraemer, W. J., Cahill, B., Chandler, J., Dziados, J., Elfrink, L., Forman, E., Gaudiose, M., Micheli, L., Nitka, M. & Roberts, S. (1996). Position Statement paper and literature Review. *Strength Cond. J., 18*, 62-76.

Faigenbaum, A. D. & Myer, G. D. (2009). Resistance training among young athletes: safety, efficacy and injury prevention effects. *Br J Sports Med, 44*, 56-63.

Faigenbaum, A. D. & Myer, G. D. (2010). Pediatric resistance training: benefits, concerns, and program design considerations Curr. *Sports Med. Rep, 9*, 161-168.

Falk, B. (1996). [Resistance-training in children and adolescents]. *Harefuah, 130*, 778-783.

Garcia-Artero, E., Ortega, F. B., Ruiz, J. R., Mesa, J. L., Delgado, M., Gonzalez-Gross, M., Garcia-Fuentes, M., Vicente-Rodriguez, G., Gutierrez, A. & Castillo, M. J. (2007). [Lipid and metabolic profiles in adolescents are affected more by physical fitness than physical activity (AVENA study)]. *Rev Esp Cardiol, 60*, 581-588.

Koutures, C. G. & Gregory, A. J. (2010). Injuries in youth soccer. *Pediatrics, 125*, 410-414.

Lubans, D. R., Morgan, P. J., Cliff, D. P., Barnett, L. M. & Okely, A. D. (2010). Fundamental movement skills in children and adolescents: review of associated health benefits. *Sports Med, 40*, 1019-1035.

Maffulli, N., Longo, U. G., Spiezia, F. & Denaro, V. (2010). Sports Injuries in young long-term outcome and prevention strategies. *The Physician and Sports Medicine, 38*, 29-34.

Malina, R., Bouchard, C. & Bar-Or, O. (2004). *Growth, Maturation and Physical Activity,* Champaigm, IL, Human Kinetics.

Mickle, K. J., Munro, B. J. & Steele, J. R. (2011). Gender and age affect balance performance in primary school-aged children. *J Sci Med Sport, 14*, 243-8.

Mikkelsson, L. O., Nupponen, H., Kaprio, J., Kautiainen, H., Mikkelsson, M. & Kujala, U. M. (2006). Adolescent flexibility, endurance strength, and physical activity as predictors of adult tension neck, low back pain, and knee injury: a 25 year follow up study. *Br J Sports Med, 40*, 107-13.

Myer, G. D., Faigenbaum, A. D., Chu, D. A., Falkel, J., Ford, K. R., Best, T. M. & Hewett, T. E. (2011a). Integrative training for children and adolescents: techniques and practices for reducing sports-related injuries and enhancing athletic performance. *Phys Sportsmed, 39*, 74-84.

Myer, G. D., Faigenbaum, A. D., Ford, K. R., Best, T. M., Bergeron, M. F. & Hewett, T. E. (2011b). When to Initiate Integrative Neuromuscular Training to Reduce Sports-Related Injuries and Enhance Health in Youth? *Curr Sports Med Rep, 10*, 155-166.

Myer, G. D., Ford, K. R., Palumbo, J. P. & Hewett, T. E. (2005). Neuromuscular training improves performance and lower-extremity biomechanics in female athletes. *J Strength Cond Res, 19*, 51-60.

Myer, G. D., Paterno, M. V., Ford, K. R. & Hewett, T. E. (2008). Neuromuscular training techniques to target deficits before return to sport after anterior cruciate ligament reconstruction. *J Strength Cond Res, 22*, 987-1014.

Myer, G. D., Quatman, C. E., Khoury, J., Wall, E. J. & Hewett, T. E. (2009). Youth versus adult "weightlifting" injuries presenting to United States emergency rooms: accidental versus nonaccidental injury mechanisms. *J Strength Cond Res, 23*, 2054-60.

Myer, G. D. & Wall, E. J. (2006). Resistance Training in the Young Athlete Oper Tech. *Sports Med, 14*, 218-230.

Payne, V. G., Morrow, J. R., Jr., Johnson, L. & Dalton, S. N. (1997). Resistance training in children and youth: a meta-analysis. *Res Q Exerc Sport, 68*, 80-88.

Ruiz, J. R., Ortega, F. B., Warnberg, J., Moreno, L. A., Carrero, J. J., Gonzalez-Gross, M., Marcos, A., Gutierrez, A. & Sjostrom, M. (2008). Inflammatory proteins and muscle strength in adolescents: the Avena study. *Arch Pediatr Adolesc Med, 162*, 462-468.

Shanmugam, C. & Maffulli, N. (2008). Sports injuries in children. *British Medical Bulletin, 86*, 33-57.

Slining, M., Adair, L. S., Goldman, B. D., Borja, J. B. & Bentley, M. (2010). Infant overweight is associated with delayed motor development. *J Pediatr, 157*, 20-25 e1.

Vicente-Rodriguez, G., Ara, I., Perez-Gomez, J., Serrano-Sanchez, J. A., Dorado, C. & Calbet, J. A. (2004). High femoral bone mineral density accretion in prepubertal soccer players. *Med Sci Sports Exerc, 36*, 1789-95.

Viru, A., Loko, J., Maarike, H., Volver, A., Laaneots, L. & Viru, M. (1999). Critical periods in the development of performance capacity during childhood and adolescence. *European Journal of Applied Physiology, 4*, 75-119.