CRONOS Pediatric Physical Activity

Resistance training and pediatric health

Entrenamiento de fuerza y salud pediátrica

Faigenbaum, A.D. [1], Myer, G.D. [2, 3, 4, 5]

[1] Department of Health and Exercise Science. The College of New Jersey, Ewing, New Jersey USA.
[2] Division of Sports Medicine, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio, USA.
[3] Departments of Pediatrics and Orthopaedic Surgery, College of Medicine, University of Cincinnati, Cincinnati, Ohio, USA.
[4] Athletic Training Division, School of Allied Medical Professions, The Ohio State University, Columbus, Ohio, USA.
[5] Departments of Athletic Training, Sports Orthopaedics, and Pediatric Science Rocky Mountain University of Health Professions, Provo, Utah, USA.

Contact details
Avery Faigenbaum: faigenba@tcnj.edu
Reception day: 28th of March , 2011
Accetance date: 20th of May, 2011

ABSTRACT
Although some clinicians and youth coaches once considered resistance training unsafe and potentially injurious to the developing musculoskeletal system, a compelling body of scientific evidence indicates that resistance exercise can be a safe, effective and worthwhile method of conditioning for children and adolescents provided age-appropriate training guidelines are followed. The qualified acceptance of supervised and well-designed youth resistance training programs by medical, fitness and sport organizations has become widespread and current public health objectives now aim to increase the number of boys and girls who participate in muscle strengthening activities. In addition to increasing muscular strength, regular participation in a pediatric resistance training program can facilitate weight control, strengthen bone, enhance motor skill performance and increase a young athletes' resistance to sports-related injuries. In this article, the importance of enhancing muscular strength early in life will be discussed, the potential health-related benefits associated with youth resistance training will be reviewed, and program design considerations for developing youth resistance training programs will be outlined.

Key Words: Strength training, weightlifting, motor skills, young athlete, physical education.

RESUMEN
Aunque muchos médicos y jóvenes entrenadores consideran que el entrenamiento de fuerza es potencialmente peligroso e inseguro para el sistema músculo esquelético en desarrollo, una gran cantidad de evidencias científicas

indican que este tipo de entrenamiento es seguro, efectivo y constituye una metodología adecuada para niños y jóvenes siempre que se sigan las indicaciones apropiadas. Los programas de entrenamiento de fuerza para niños y jóvenes, si son adecuadamente diseñados y supervisados por profesionales cualificados son actualmente aceptados por las organizaciones médicas y deportivas, las cuales consideran que el incremento del número de niños y niñas que realicen entrenamiento de fuerza debe ser uno de los objetivos actuales para promover la salud pública. Además de incrementar los niveles de fuerza muscular, la participación regular en programas de entrenamiento de fuerza en niños ayuda a controlar el peso corporal, aumentar la fortaleza de los huesos, mejorar las habilidades motoras y reducir la incidencia de lesiones en los jóvenes deportistas. En este artículo se analizará la importancia de mejorar la fuerza muscular en las edades tempranas, los beneficios potenciales para la salud asociados con el entrenamiento de fuerza en jóvenes y las consideraciones más importantes que deben tenerse en cuanta para diseñar programas de entrenamiento adecuados para desarrollar la fuerza en jóvenes

Palabras clave: Entrenamiento de fuerza, levantamiento de peso, habilidades motoras, deportistas jóvenes, educación física.

INTRODUCTION

A growing number of children and adolescents are participating in resistance training programs in sport centers and contemporary physical education programs now include strength-building activities as part of a health-enhancing approach to fitness education (A. Faigenbaum et al., 2009; National Association for Sport and Physical Education, 2011). Nowadays, evidence-based reports regarding the both the safety and efficacy of resistance training in children and adolescents are common and the acceptance of pediatric resistance training by medical, fitness and sport organizations has become widespread (A. Faigenbaum, et al., 2009; A. Faigenbaum & Myer, 2010b; American College of Sports Medicine, 2010; Behm, Faigenbaum, Falk, & Klentrou, 2008; British Association of Exercise and Sport Sciences, 2004; Malina, 2006). As more children and adolescents resistance train in schools, recreation centers, and sport training facilities, it is important to understand both the potential benefits of resistance exercise and establish safe and effective practices by which this type of conditioning can improve the health of younger populations. In addition, as many parents and youth coaches want to know the age at which children can start resistance training, guidelines for initiating participation in structured strength and conditioning activities are discussed.

In the current article, the term resistance training refers to a method of conditioning that involves the progressive use of a wide range of resistive loads, different movement velocities and a variety of training modalities including weight machines, free weights (dumbbells and barbells), elastic bands, medicine balls and body weight. For simplicity, the terms pediatric and youth refer to both children (Tanner stages 1 and 2 of sexual maturation; approximately up to age 12 years) and adolescents (Tanner stages 3 and 4 of sexual maturation; approximately 13 to 18 years).

Physical Activity for Youth

Several organizations have developed physical activity guidelines for children and adolescents and it generally agreed that youth should participate daily in 60 minutes or more of moderate to vigorous physical activity (MVPA) that is developmentally appropriate, enjoyable and involves a variety of activities (Martinez-Gomez et al., 2010; Strong et al., 2005; United States Department of Health and Human Services, 2008). Regular participation in MVPA helps to reduce body fat, improve blood lipids, build skeletal tissue, strengthen muscles, and improve aerobic fitness (Gutin & Owens, 2011; Strong, et al., 2005). Moreover, well-designed physical activity programs can enhance motor performance skills, reduce the risk of injuries in youth sports and simply makes boys and girls feel better about themselves (National Association for Sport and Physical Education, 2011; Valovich McLeod et al., 2011). Recent studies have also shown positive relationships between school-based physical activity and academic achievement (Centers for Disease Control and Prevention, 2010).

Perhaps of greater importance is the observation that health-related behaviors that are acquired during childhood and adolescence are likely to be carried into adulthood (Telama, 2009). In fact, it appears that youth who master fundamental movement skills and gain confidence in their physical abilities are more likely to be active later in life (Barnett, Van Beurden, Morgan, Brooks, & Beard, 2008; Barnett, Van Beurden, Morgan, Brooks, & Beard, 2009; Stodden, Langendorfer,

& Roberton, 2009). Fundamental movement skills are commonly developed during childhood and include locomotor (e.g., hopping), object control (e.g., catching) and stability (e.g., balancing) skills. As illustrated in figure 1, a child's motor skill competence and proficiency can *drive* participation in health-related fitness activities (e.g. adequate amounts of MVPA), which, in turn, may increase the likelihood that this positive lifestyle choice will be carried over into adulthood.

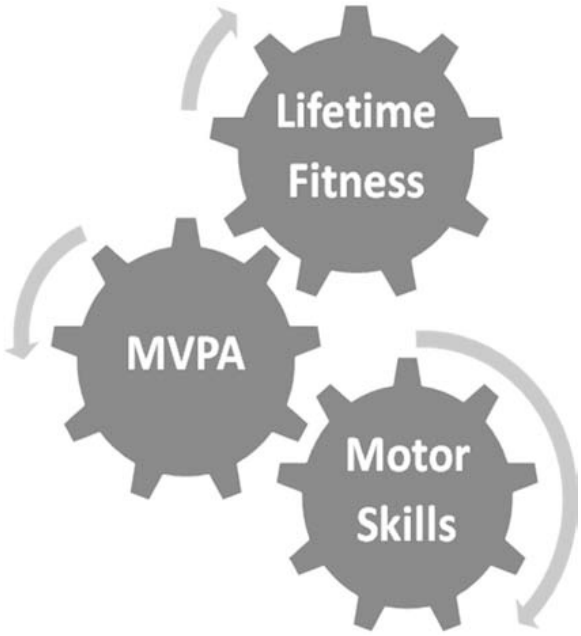

Figure 1. Improved motor skill performance can drive participation in moderate to vigorous physical activity (MVPA) which in turn can improve lifetime fitness.

Conversely, children who do not develop fundamental movement skills early in life may not be able to break through a hypothetical "proficiency barrier" later in life that would allow them to participate in a variety of sports and activities with confidence and vigor (Seefeldt, 1980). Current findings suggest that the eventual decline and disinterest in physical activity during this critical period of life may be a contemporary corollary of reduced motor skill proficiency and low muscle strength (Cohen et al., 2011; Runhaar et al., 2010). That is, by middle childhood children more acutely compare their physical prowess to others and it is this perception of competence that can influence their persistence in a task or activity (Eccles & Wigfield, 2002; Harter, 1978). By age 10, some children with relatively low levels of muscle strength and skill-related performance begin to perceive that they are not as good as their peers. Consequently, these unfit youth chose to disengage from exercise and sport and gravitate towards sedentary "safe" activities. Thus, one of the primary goals of youth resistance training is to engage boys and girls in a variety of strength-building activities that refine fundamental movement skills and enhance their perceived confidence in their abilities to be physically active.

Potential Health-related Benefits

During childhood and adolescence, many physiological changes related to growth and development occur at a rapid rate. During this period, healthy children and adolescents will show noticeable gains in height, weight, and measures of physical fitness during the developmental years. For example, muscular strength normally increases from childhood through the early teenage years, at which time there is a marked acceleration in strength in boys and a general plateau in strength in girls (Malina, Bouchard, & Bar-Or, 2004). Yet despite these age-related gains in muscular fitness, a compelling body of scientific evidence indicates that children and adolescents can significantly increase their muscle strength above and beyond growth and development providing that the resistance training program is of sufficient duration, intensity and volume (Behringer, Vom Heede, Yue, & Mester, 2010; Faigenbaum & Myer, 2010a; Myer, Faigenbaum, Ford et al., 2011). Children as young as age six have benefited from resistance training (Faigenbaum, Westcott, Loud & Long, 1999; Weltman et al., 1986) and studies lasting two to three school years have been reported with positive adaptions in the study participants (Falk et al., 2002; Sadres, Eliakim, Constantini, Lidor & Falk, 2001).

Resistance training can offer unique health and fitness benefits to children and adolescents provided that appropriate training guidelines are followed. In addition to enhancing muscle strength, the safe and proper prescription of resistance exercise has been shown to favorably influence cardiovascular risk, body composition, bone mineral density, psychosocial well-being, and resistance to sports-related injuries (Behm et al., 2008; Faigenbaum, 2007; Myer, Faigenbaum, Chu et al., 2011; Valovich McLeod et al., 2011). More recently, a meta-analysis demonstrated that regular participation in a structured resistance training program can significantly improve running, jumping and throwing performance in children and adolescents (Behringer, Vom Heed, Methews & Mester, 2011). Since these motor performance skills provide the foundation for participation in exercise and sport, these important findings highlight the potential salutary effects of youth resistance training on lifetime physical activity. In the aforementioned report (Behringer et al., 2011), the highest effect sizes

were observed in studies that combined traditional resistance training with plyometric training, although differences between combined training and solo training (i.e., resistance training or plyometric training alone) on motor performance skills did not reach statistical significance.

Although various training modalities and a variety of training regimens have been used, all the training programs used in research studies were closely supervised and appropriately prescribed to ensure that the training program was matched to the initial capacity of the child. In the vast majority of resistance training intervention studies, the injury occurrence in children and adolescents was either very low or nil and the resistance training stimulus was well-tolerated by the young subjects (Faigenbaum & Myer, 2010b; Malina, 2006). Of interest, significant gains in strength without any report of injury have been reported in prospective studies in which weightlifting movements (including modified cleans, pulls and presses) were incorporated into youth resistance training programs (Faigenbaum & McFarland, 2008). These findings are supported by observations from others who found that the sport of weightlifting can be safe for youth provided that well-informed coaches supervise all training sessions and competitions in order to carefully prescribe the weight lifted (Byrd, Pierce, Rielly & Brady, 2003).

While the both the safety and efficacy of pediatric resistance training applied has been strongly supported in the scientific literature, youth coaches and physical education teachers need to be keenly aware of proper resistance training procedures to prevent the aggressive progression of training loads and the development of poor exercise technique that can be injurious in lifters of any age (Lavallee & Balam, 2010; Greg Myer, Quatman, Khoury, Wall & Hewett, 2009). A recurring theme in most youth resistance training-related injuries is the lack of qualified adult supervision and instruction. However, with guidance from qualified professionals in a safe training environment, neuromuscular deficits can be identified and successfully treated. For example, in figure 2 pre-training neuromuscular deficits are observable in an 8 year old girl performing the back squat exercise. Following resistance training which included instruction and practice to address these neuromuscular deficits, her exercise performance and perceived confidence to perform multi-joint lifts improved (Figure 3).

Professionals who prescribe and supervise youth resistance training programs should be cognizant of the potential for injury and should attempt to reduce injuries through the identification of risk factors and injury patterns in young lifters. Modifiable risk factors associated with youth resistance training injuries which can be reduced or eliminated with qualified supervision and instruction are outlined in table 1 (Faigenbaum, Myer, Naclerio & Casas, 2011). While these risk factors are applicable to most youth training programs, it is important to realize that each sport or activity poses its own risk for injury and each participant may have individual risk factors related to their physical and psychological well-being.

Figure 2. An untrained child demonstrating neuromuscular deficits while performing the squat exercise.

Figure 3. A trained child demonstrating improved squat performance following participation in a resistance training program that targeted individual needs.

Table 1. Modifiable risk factors associated with resistance training injuries in children and adolescents which can be reduced (or eliminated) with qualified supervision and instruction*.

Risk Factor	Modification by Qualified Professional
Unsafe exercise environment	Adequate training space and proper equipment layout
Improper equipment storage	Secure storage of exercise equipment
Unsafe use of equipment	Instruction on safety rules in the training area
Excessive load & volume	Prescription and progression of training program driven by technical performance of prescribed exercise movement
Poor exercise technique	Clear instruction and feedback on exercise movements
Poor trunk control	Targeted neuromuscular training
Muscle imbalances	Training program includes agonist and antagonist exercises
Previous injury	Communicate with treating clinician and modify program
Sex-specific growth	Targeted training to address deficits
Inadequate recuperation	Incorporate active rest and consider lifestyle factors such as proper nutrition and adequate sleep

* *From Faigenbaum, Myer, Naclerio, & Casas, 2011*

Pediatric Resistance Training Guidelines

Although there is no minimum age for participation in a youth resistance training program, all participants must be able to follow coaching instructions and undergo the stress of a resistance training program. In our youth programs, we introduce 6 and 7 year old children to resistance training activities using body weight activities and external loads (Faigenbaum et al., in press; Faigenbaum et al., 1999). However, regardless of the starting age, all youth should receive safety instructions from qualified professionals on proper exercise technique, appropriate exercise behavior, sensible starting loads and the correct handling of exercise equipment. This is particularly important in schools and recreation centers because untrained youth tend to overestimate their physical abilities and this may increase their risk of injury. This type of instruction not only enhances participant safety and enjoyable of the training experience, but direct supervision of youth resistance training programs can improve program adherence and optimize strength gains (Coutts, Murphy & Dascombe, 2004).

There does not appear to be one "optimal" combination of sets, repetitions, and exercises that will promote favorable adaptations in young athletes. Rather, the sensible integration of different training methods and the periodic manipulation of program variables over time will keep the training stimulus effective, challenging and enjoyable for the participants. We refer to this concept as integrative neuromuscular training because it incorporates a combination of performance-enhancing and injury-reducing components (e.g., strength, power, and balance) into one fitness program (Myer, Faigenbaum, Chu et al., 2011). This type of training does not necessitate expensive equipment, but it does require qualified instruction, a systematic progression of training variables, and an understanding of pediatric exercise guidelines.

Program design variables that should be considered when designing pediatric resistance training programs include: 1) choice of exercise, 2) training intensity and 3) training volume. From our experience, resistance training with free weights, medicine balls and one's own body weight may be particularly beneficial for youth who need to enhance motor skill performance, balance, core strength, and muscle power as part of an *integrated* training program. Increased dynamic balance may help to provide children and adolescents with a stable core (i.e., pelvis, abdomen, trunk and hip) that will be better prepared to respond to the high forces generated at the distal body parts during fitness activities and athletic events (Myer, Chu, Brent, & Hewett, 2008).

Training intensity typically refers to the amount of resistance used for a specific exercise whereas training volume generally refers to the total amount of work performed in a training session. Although different combinations of sets and repetitions have be used in research studies, in a recent analysis that examined the

effects of resistance training on children and adolescents, the average training program consisted of 2 to 3 sets with 8 to 15 repetitions and loads between 60% and 80% of the 1 repetition maximum on 6 to 8 exercises (Behringer et al., 2010). While these observations are in accordance with youth resistance training guidelines from the National Strength and Conditioning Association (Faigenbaum, et al., 2009), youth must first learn how to perform each exercise correctly with a light load and then gradually progress the training intensity and/or volume without compromising exercise technique. Detailed descriptions of youth resistance training programs using different types of equipment are beyond the scope of this article but are available elsewhere (Faigenbaum & Westcott, 2009).

CONCLUSION

Scientific evidence and clinical impressions indicate that resistance training has the potential to offer observable health value to children and adolescents provided that appropriate training guidelines are followed and qualified instruction is available. Although training-induced benefits are observable at any age, it may be particularly beneficial to initiate resistance training during preadolescence. Comprehensive pediatric training programs that *integrate* different elements of resistance exercise are most likely to enhance fundamental movement skills, reduce the risk of injury, and promote lifelong physical activity. Important future research goals should aim to elucidate the mechanisms responsible for the performance enhancement and injury reduction benefits associated with pediatric resistance exercise, establish the combination of program variables that may optimize training adaptations and exercise adherence in children and adolescents, and explore the long-term effects of resistance exercise on the health and fitness of school-age youth.

ACKNOWLEDGEMENTS

Gregory Myer would like to acknowledge funding support from the National Institutes of Health Grants R01-AR049735 and R01-AR055563.

REFERENCES

American College of Sports Medicine. (2010). *ACSM's Guidelines for Exercise Testing and Prescription* (8th ed.). Baltimore, MD: Lippincott, Williams and Wilkins.

Barnett, L., Van Beurden, E., Morgan, P., Brooks, L. & Beard, J. (2008). Does childhood motor skill proficiency predict adolescent fitness? *Medicine and Science in Sports and Exercise, 40* (12), 2137-2144.

Barnett, L., Van Beurden, E., Morgan, P., Brooks, L. & Beard, J. (2009). Childhood motor skill proficiency as a predictor of adolescent physical activity. *Journal of Adolescent Health, 44*, 252-259.

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* (3), 547-561.

Behringer, M., vom Heed, A., Metthews, M. & Mester, J. (2011). Effects of strength training on motor performance skills in children and adolescents: A meta-analysis. *Pediatric Exercise Science, 23* (2), 186-206.

Behringer, M., vom Heede, A., Yue, Z. & Mester, J. (2010). Effects of resistance training in children and adoelscents: A meta-analysis. *Pediatrics, 126* (5), e1199-e1210.

British Association of Exercise and Sport Sciences. (2004). BASES position statement on guidelines for resistance exercise in young people. *Journal of Sport Sciences, 22*, 383-390.

Byrd, R., Pierce, K., Rielly, L. & Brady, J. (2003). Young weightlifters' performance across time. *Sports Biomechanics, 2*, 133-140.

Centers for Disease Control and Prevention. (2010). *The Association Between School-Based Physical Activity, Including Physical Education, and Academic Performance*. Atlanta, GA: U.S. Department of Health and Human Services.

Cohen, D., Vioss, C., Taylor, M., Delextrat, A., Ogunleye, A. & Sandercock, G. (2011). Ten-year secular changes in muscular fitness in English children. *Acta Paediatrica*.

Coutts, A., Murphy, A. & Dascombe, B. (2004). Effect of direct supervision of a strength coach on measures of muscular strength and power in young rugby league players. *Journal of Strength and Conditioning Research, 18*, 316-323.

Eccles, J. & Wigfield, A. (2002). Motivational beliefs, values and goals. *Annual Review of Psychology, 53*, 109-132.

Faigenbaum, A. (2007). Resistance training for children and adolescents: Are there health outcomes? . *American Journal of Lifestyle Medicine, 1*, 190-200.

Faigenbaum, A., Farrel, A., Fabiano, M., Radler, T., Naclerio, F., Ratamess, N., et al. (in press). Effects of integrative neuromuscular training on fitness performance in children. *Pediatric Exercise Science*.

Faigenbaum, A., Kraemer, W., Blimkie, C., Jeffreys, I., Micheli, L., Nitka, M., et al. (2009). Youth resistance training: Updated position statement paper from the National Strength and Conditioning Association. *Journal of Strength and Conditioning Research, 23* (Supplement 5), S60-S79.

Faigenbaum, A. & McFarland, J. (2008). Relative safety of weightlifting movements for youth. *Strength and Conditioning Journal, 30* (6), 23-25.

Faigenbaum, A. & Myer, G. (2010a). Pediatric resistance training: Benefits, concerns and program design considerations. *Current Sports Medicine Reports, 9* (3), 161-168.

Faigenbaum, A. & Myer, G. (2010b). Resistance training among young athletes: Safety, efficacy and injury prevention effects. *British Journal of Sports Medicine, 44*, 56-63.

Faigenbaum, A., Myer, G., Naclerio, F. & Casas, A. (2011). Injury trends and prevention in youth resistance training. *Strength and Conditioning Journal, 33* (3), 36-41.

Faigenbaum, A., & Westcott, W. (2009). *Youth Strength Training*. Champaign, IL: Human Kinetics.

Faigenbaum, A. D., Westcott, W. L., Loud, R. L. & Long, C. (1999). The effects of different resistance training protocols on muscular strength and endurance development in children. *Pediatrics, 104* (1), e5.

Falk, B., Sadres, E., Constantini, N., Zigel, L., Lidor, R. & Eliakim, A. (2002). The association between adiposity and the response to resistance training among pre- and early-pubertal boys. *J Pediatr Endocrinol Metab, 15* (5), 597-606.

Gutin, B. & Owens, S. (2011). The influence of physical activity on cardiometabolic biomarkers in youths: A review. *Pediatric Exercise Science, 23* (2), 169-185.

Harter, S. (1978). Effectance motivation reconsidered: Toward a developmental model. *Human Development, 21*, 34-64.

Lavallee, M. & Balam, T. (2010). An overview of strength training injuries: Acute and chronic. *Current Sports Medicine Reports, 9* (5), 307-313.

Malina, R., Bouchard, C. & Bar-Or, O. (2004). *Growth, Maturation and Physical Activity* (2nd ed.). Champaigm, IL: Human Kinetics.

Malina, R. M. (2006). Weight training in youth-growth, maturation, and safety: an evidence-based review. *Clin J Sport Med, 16* (6), 478-487.

Martinez-Gomez, D., Ruiz, J., Ortega, F., Veiga, O., Moliner-Urdiales, D., Mauro, B. et al. (2010). Recommended levels of physical activity to avoid an excess of body fat in European adolescents. *American Journal of Preventive Medicine, 39* (3), 203-211.

Myer, G., Faigenbaum, A., Chu, D., Falkel, J., Ford, K. & Best, T. (2011). Integrative training for children and adolescents: Techniques and practices for reducing sports-related injuries and enhancing athletic performance. *The Physician and Sportsmedicine, 39* (1), 74-84.

Myer, G., Faigenbaum, A., Ford, K., Best, T., Bergeron, M. & Hewett, T. (2011). When to initiate integrative neuromuscular training to reduce sports-related injuries and enhance health in youth? *Current Sports Medicine Reports, 10* (3), 157-166.

Myer, G., Quatman, C., Khoury, J., Wall, E. & Hewett, T. (2009). Youth vs. adult "weightlifting" injuries presented to United States Emergengy Rooms: Accidental vs. non-accidental injury mechanisms. *Journal of Strength and Conditioning Research, 23* (7), 2054-2060.

Myer, G. D., Chu, D. A., Brent, J. L. & Hewett, T. E. (2008). Trunk and hip control neuromuscular training for the prevention of knee joint injury. *Clin Sports Med, 27* (3), 425-448, ix.

National Association for Sport and Physical Education. (2011). *Physical Education for Lifetime Fitness* (3rd ed.). Champaign, IL: Human Kinetics.

Runhaar, J., Collard, D. C., Singh, A., Kemper, H. C., Van Mechelen, W. & Chinapaw, M. (2010). Motor fitness in Dutch youth: differences over a 26-year period (1980-2006). *Journal of Science and Medicine in Sport, 13*, 323-328.

Sadres, E., Eliakim, A., Constantini, N., Lidor, R. & Falk, B. (2001). The effect of long term resistance training on anthropometric measures, muscle strength and self-concept in pre-pubertal boys. *Pediatric Exercise Science, 13*, 357-372.

Seefeldt, V. (1980). Developmental motor patterns: Implications for elementary school physical education. In C. Nadeau, W. Holliwell, K. Newell & G. Roberts (Eds.), *Psychology of Motor Behavior and Sport* (pp. 314-323). Champaign, IL: Human Kinetics.

Stodden, D., Langendorfer, S., & Roberton, M. (2009). The association between motor skill competence and physical fitness in young adults. *Research Quarterly for Exercise and Sport, 80* (2), 223-229.

Strong, W. B., Malina, R. M., Blimkie, C. J., Daniels, S. R., Dishman, R. K., Gutin, B. et al. (2005). Evidence based physical activity for school-age youth. *J Pediatr, 146* (6), 732-737.

Telama, R. (2009). Tracking of physical activity from childhood to adulthood: a review. *Obesity Facts, 2* (3), 187-195.

United States Department of Health and Human Services. (2008). 2008 Physical Activity Guidelines for Americans

Valovich McLeod, T., Decoster, L., Loud, K., Micheli, L., parker, J., Sandrey, M. et al. (2011). National Athletic Trainers' Association position statement: Prevention of pediatric overuse injuries. *Journal of Athletic Training, 46* (2), 206-220.

Weltman, A., Janney, C., Rians, C., Strand, K., Berg, B., Tippitt, S. et al. (1986). The effects of hydraulic resistance strength training in pre-pubertal males. *Medicine and Science in Sports and Exercise, 18* (6), 629-638.