Exercise Deficit Disorder in Youth: A Paradigm Shift toward Disease Prevention and Comprehensive Care

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Abstract
Despite the widely recognized benefits of daily play, recreation, sports, and physical education on the physical and psychosocial well-being of children and adolescents, many contemporary children and adolescents worldwide do not meet the recommendations for daily physical activity (PA). The decline in PA seems to start early in life, which leads to conditions characterized by reduced levels of PA in the pediatric population that are inconsistent with current public health recommendations. Unlike many other diseases and disorders in pediatrics, physical inactivity in youth is unique in that it currently lacks a clinical gold standard for diagnosis. This makes the diagnosis and treatment medically challenging, though no less important, as the resultant ramifications of a missed diagnosis are of significant detriment. Exercise-deficient children need to be identified early in life and treated with developmentally appropriate exercise programs designed to target movement deficiencies and physical weaknesses in a supportive environment. Without such interventions early in life, children are more likely to become resistant to our interventions later in life and consequently experience adverse health consequences. Integrative approaches that link health care professionals, pediatric exercise specialists, school administrators, community leaders, and policy makers may provide the best opportunity to promote daily PA, reinforce desirable behaviors, and educate parents about the exercise-health link.

Introduction
The health of a population may be assessed via psychological, social, and physical measures including mental health, tobacco use, nutritional status, and physical activity (PA) habits (73). Despite noteworthy advancements in both medicine and technology, most health measures of the U.S. population are getting worse, as obesity and weight-related comorbidities continue to increase (22,49). Obesity, despite being the most preventable cause of mortality in the United States and worldwide, continues to increase at an alarming rate among children and adults. Currently approximately 365,000 deaths are attributed to poor diet and physical inactivity in the United States per annum (38). Since the first National Health and Nutrition Examination Survey in the 1960s, the prevalence of overweight and obese children aged 6 to 11 years has increased threefold (4.2% in the early 1960s to 15.8% in 2002) (22). Alarmingly forecasts that are more recent indicate that by the year 2030, 42% of the American population will be obese, with severe obesity prevalence increasing 130% over these next two decades (21). While the etiology for the observed decline in child and adult health is likely multifactorial, a reduction in PA may well be an underlying mechanism. Particularly troubling are recent epidemiological reports indicating that contemporary youth are not as active as children should be or used to be (5,47,69), and the decline and disinterest in PA progresses steadily after the age of 6 years (25,32,69).

Obesity, despite being the most preventable cause of mortality worldwide, continues to increase at an alarming rate among children and adults. Without a change in management strategies, these trends are unlikely to change. In
addition, health care efforts targeting overweight or obese youth will continue to encourage disease-oriented treatment strategies, which likely are to be ineffective long term (51,64). The increased prevalence of physical inactivity in school-age children may be exacerbated by recent school budget constraints, lack of qualified physical education professionals, and the widespread implementation of standardized academic testing programs (60). Collectively these factors contribute to a negative impact on the time and resources available for health and physical education programs designed to provide students with the knowledge, skills, and confidence they need to engage regularly in a variety of PAs.

Today, children are provided nearly continuous opportunity for screen time (TV, video games, computers, and cell phones) at the cost of opportunities for PA (Fig. 1). As no child is immune from our contemporary lifestyle, a team approach that links physicians, physical educators, pediatric exercise specialists, and public health officials may be needed to identify youth at risk and to promote healthy lifestyle choices for all youth, regardless of body size or physical ability. Recent findings indicate that motor coordination is a predictor of PA in childhood (24,26,34). This emphasizes the importance of early recognition of motor skill deficiency in children and necessity of systematic instruction and skilled training to improve childhood motor proficiency during formative and developmental periods of life.

The need to identify and target deficiencies in muscle strength and motor skill ability early in childhood is critically important, as PA behaviors and lifestyle habits established during childhood tend to track into adulthood (65). Exercise-deficit disorder (EDD) is a term recently introduced to the medical literature to describe a state of low PA, which is inconsistent with the current public health recommendations (16). It is unlike many other diseases and disorders; EDD is unique in that it does not have established clinical markers or laboratory tests to make the definitive diagnosis. Moreover there are no medications to treat deficiencies in movement skill or PA (12,14,15). As we have learned from casual smoking, the adverse health consequences arise from an initial lifestyle choice. Today smoking addiction is aggressively identified and treated due to the known benefits of timely intervention. Similarly sedentary lifestyles in youth may arise from environments that are not enriched with developmentally appropriate PA outlets. Recent trends indicate that PA has become a leading risk factor for morbidity and mortality. Associated physical inactivity-related outcomes are magnified potentially and lifestyle habits more resistant to change if they emerge during youth and adolescence. Consequently sedentary youth need to be identified early in life and referred to pediatric exercise specialists who specially are equipped to intervene with developmentally appropriate and enjoyable exercises that are designed to target movement deficiencies and physical weaknesses. Given the lack of effective medical treatment for physical inactivity, a preventive strategy consisting of the integration of physical fitness and enhancement of a child’s motor skill confidence and competence is needed to prevent the eventual decline and disinterest in this desired behavior (39,42,44).

Prior reports raise two fundamental questions: First, are contemporary youth prepared to participate daily in 60 min or more of moderate to vigorous PA (MVPA) in order to meet public health recommendations? Second, within our current health care system, who is qualified and willing to identify and treat children with EDD? The purpose of this review is to present an integrative model that links health care providers with pediatric exercise specialists. This model supports a synergistic approach to the identification of inactive children and the development of a treatment plan, which enhances the health- and skill-related fitness of children and adolescents with different needs, goals, and abilities.

**Integrative Health Care**

The potential impact of physical inactivity and obesity on health service utilization and costs during childhood has created a need for immediate action to manage and prevent high-risk behaviors during this critical period of life (14,19,67). There is increasing evidence that sedentary behavior during childhood may result in a vortex of physical inactivity culminating in negative health outcomes that will stress ultimately the health care system later in life (Fig. 2) (14,19,37,59). This downward spiral, beginning with childhood inactivity and ending in poor health, emphasizes the crucial need for early identification and treatment of the physically inactive child, before he or she becomes resistant to our interventions.

Primary care physicians, school nurses, and certified athletic trainers are well positioned to promote injury prevention strategies that enhance the health and well-being of children and adolescents (11,15,16,61). While many health care providers perform routine screening surrounding vision, hearing, and body mass index (BMI), most interactions are essentially void of any meaningful assessment of PA (20). Providing clinicians with a method of identifying early and effectively the physically inactive child enables timely intervention and treatment (12). Once identified, the child with EDD can be referred to a pediatric exercise specialist who has the requisite pedagogical and physiological content knowledge to design, implement, and progress developmentally appropriate activity programs (Fig. 3).

If exercise is medicine and a prescription of “exercise as medicine” is expected, then why is medical education limited with instruction in exercise science? A recently published survey of sports and exercise medicine practitioners indicated that there was no substantive teaching of sports and exercise medicine in the core medical curricula in Australia, Canada,
now or pay later. Faigenbaum AD, Myer GD. Exercise deficit disorder in youth: play active, which will further stress the health care system [Adapted from show incremental increases and likely will be in most part ineffec-
tive. As children digress into the inactivity vortex, the related health care costs to treat deficits will demonstrate the great effectiveness. As children digress into the inactivity vortex, the related health care costs to treat deficits will likely be in part ineffective, which will further stress the health care system [Adapted from Faigenbaum AD, Myer GD. Exercise deficit disorder in youth: play now or pay later. Curr. Sports Med. Rep. 2012;11(4):196–200. Copyright © 2012. American College of Sports Medicine. Used with permission.]

Integrative Education
Physically active children and adolescents, as compared to their inactive counterparts, demonstrate increased levels of musculoskeletal strength, enhanced cardiorespiratory function, and improved metabolic health (30, 62, 70). In fourth and fifth grade children, the addition of an after school soccer program effectively decreased BMI z-scores at 3 and 6 months and influenced increases in total daily, moderate, and vigorous PA at 3 months (71). Furthermore regular participation in well-designed sport programs is associated with increased energy expenditure and aerobic fitness levels compared with nonsports participants. Therefore sports participation may be a potentially effective strategy to improve PA and health measures in children and adolescents who are prepared for the demands of sports practice and competition (50, 74). In young girls, sports team participation was associated with increased PA and reduced television viewing and BMI in a dose-response fashion (57). In this same pattern, fifth grade children who participated in recreational sport programs throughout the year (fall, winter, and spring) demonstrated a greater level of increased fitness performance than their peers who did not participate in any sport or who only participated in one sport (27).

Continuing on, in a 10-year longitudinal study of 630 adolescents, the participants first became involved in organized youth sports clubs between the ages of 6 to 10 years old (29). Interestingly those who reported becoming members of a sports team at an earlier age were more physically active as adults than adolescents who initiated sports involvement at older ages (29). It is possible that the improved motor competence and muscle strength that developed with structured PA and play throughout the growing years facilitate the establishment of desired course in pediatric exercise within their curricula. In addition, less than 50% of physical therapy education programs in the United States require exercise science prerequisites (23). Moreover only 7% of professional pediatric physical therapy education programs require a pediatric clinical edu-
cation placement; therefore, many practicing physical thera-
pists have limited pediatric experience to develop health and wellness exercise programming for children (56). Thus while we encourage physician referral to a pediatric exercise special-
ist, current educational curricula may limit the develop-
ment of professionals trained with background to provide potential outlets for physicians to target these referrals.

Confounding the potential for early identification and treatment of risk factors in youth with EDD, the current symptom-reactive health care system is not focused on prevention but rather the treatment of the disease. This approach has been largely unsuccessful in the promotion of PA and the management of obesity and related disorders. This view is supported by the troubling increase in the prevalence of prediabetes/diabetes from 9% to 23% in U.S. adolescents aged 12 to 19 years (36). If exercise is medicine, then physicians and pediatric exercise specialists should be reimbursed for the evaluation and treatment of children with EDD with the goal of decreasing the likelihood of adverse health consequences later in life while reducing the future economic burden of lifestyle-related illnesses. Future prospec-
tive investigations are warranted to evaluate these contentions.
behaviors and habits that may carry over into adulthood (35). Regular participation in sports, play, recreation, and planned exercise designed to improve physical fitness during childhood and adolescence may provide an optimal mechanism for promoting PA as an ongoing lifestyle choice (52,53,68,73).

If children grow up in an environment that is deficient in opportunities to participate regularly in a variety of health-enhancing and skill-building activities, they may be less likely to engage in more challenging activities later in life and more likely to experience the adverse consequences of a sedentary lifestyle. This view is supported by the work of Lopes et al. (33) who reported that 6-year-old children with low and average levels of motor coordination had lower levels of PA 5 years later compared with children with high motor coordination. Others noted that low levels of PA significantly increased the risk of injury in children during physical education, recreation, and sports (6). Of interest, in the aforementioned report, the researchers found that the steepest increase in injury risk was for the quartile with the lowest habitual PA, and the cutoff for this level was 5 h of PA per week (6).

In the United States, school-based sports teams and community-based recreation programs are the most viable means for children and adolescents to participate in structured PA. These programs are often coached by well-meaning adults who may not have the requisite content knowledge or understanding of the physical and psychosocial uniqueness of school-age youth. While sports and recreation programs provide a mechanism to increase MVPA and enhance motor skill development, recent reports indicate that regular participation in organized youth sports does not ensure adequate exposure to regular PA (31,55). In addition, sports and recreational activities without preparatory neuromuscular conditioning may increase risk of injury in these young children and adolescents (6,63). While regular sports participation during childhood and adolescence is positively associated with improvements in cardiovascular, musculoskeletal, and metabolic health, recent findings indicate that a sports-related knee injury during the growing years can initiate unfavorable changes (increased BMI z-score and body fat percentage) in body composition (40). Thus children identified with EDD may not be prepared (mentally or physically) to initiate sporting activities. Referral to a pediatric exercise scientist can help in the programming of PA that can support the development of motor skills and muscular strength that are needed for game play and sport participation.

Youth who are not adequately prepared for the demands of sports training and competition may be at increased risk for injury, reduced PA, and consequent unhealthy weight gain (40). In addition, the drastic and sudden reduction in PA from either chronic pain or acute injury may initiate a "negative spiral of disengagement" whereby reduced PA leads to diminished cardiorespiratory fitness, increased adiposity, and poor health outcomes (59). Ultimately, injury during childhood sports and recreation may initiate a cascade of adverse health effects, which may manifest as sedentary lifestyle habits during adulthood (1,2,42,44,58).

For example, young girls who reported new knee injuries demonstrated significantly greater increase in BMI z-score and body fat percentage relative to their uninjured peers within 1 year of the reported injury (46). A qualified pediatric exercise specialist who possesses a specialized body of knowledge and skills is needed to develop, implement, and progress age-related exercise interventions that allow children to meet the desired objectives while learning about the benefits of an active lifestyle. There are strong inverse relationships between parental and child perceptions of injury risk and PA. As fear-related concerns centered around injury and reduction
in PA are greatest in children who are 9 to 11 years of age, implementing injury prevention programs as well as educating parents about safe sporting and PA opportunities is likely optimal and important for children 7 to 8 years of age (66).

The reduction of physical education, team sports, and organized recreation programs in some communities has negatively impacted the resources available to expose youth to a variety of positive experiences that can promote and encourage participation in PA as an ongoing lifestyle choice (7,48,54). Many school districts have reduced time for health and physical education, resulting in less athletic students and fewer opportunities for them to expand their physical, social, and problem-solving skills in the context of games, play, and structured fitness activities. Presently at the elementary school level, only three states in the country require the nationally recommended 150+ min wk \(^{-1}\)/30 min d \(^{-1}\) of physical education, and 59% of states allow required physical education credits to be earned through online courses (48). Of note, the median physical education budget for schools in the United States is only $764 per school year (48). Furthermore funding for after-school programs and athletics may be limited due to district attempts to preserve staffing, transportation, and academic programming.

Since physical inactivity is now recognized as the fourth leading risk factor for global mortality (73), long-term initiatives that aim to maintain participation in PA throughout one’s lifespan while reducing the risk of obesity and related disorders in children are warranted (60). Budgetary constraints and insular views that influence funding for and attitudes toward physical education, team sports, and after school recreation programs limit the potential for all youth to meet current recommendations for PA in a positive learning atmosphere (7). Without qualified professionals who are trained to work with inactive youth and help them develop the competence and confidence to be physically active early in life, it is unlikely that current trends in physical inactivity and childhood obesity will regress.

**Integrative Management for EDD**

A child’s level of PA is influenced by extrinsic factors (e.g., environment, family, peers, socioeconomic status, culture, and self-efficacy) that may affect their desire and ability to be physically active. Recent public health recommendations now promote aerobic training and muscle strengthening exercise activities that focus on the development of cardiorespiratory and musculoskeletal health and fitness (70,73). However general PA recommendations for school-age children (i.e., at least 60 min d \(^{-1}\) of MVPA) (70,72) may be suboptimal for children and adolescents who need to develop fundamental motor skills (e.g., jumping, throwing, and balancing) that will support participation in a variety of PA that are part of a healthy lifestyle (3,4,26,42). Youth with reduced motor skill competence and low levels of perceived confidence in their physical abilities may be less willing and able to participate in competitive sports. Moreover inactive youth often find prolonged periods of aerobic exercise to be boring or discomforting (42). The questions then remain as to what are the ideal programs required to prepare adequately children for safe participation in sport and recreation programs, and who is qualified to design and implement physical developmental programs for children?

Integrative neuromuscular training is a conceptual training model that is defined operationally as a supplemental training program that incorporates general (e.g., fundamental movements) and specific (e.g., exercises targeted to motor control deficits) strength and conditioning activities, such as resistance, dynamic stability, core-focused strength, plyometric and agility prescribed to enhance health, and skill-related components of physical fitness (Fig. 4). Integrative neuromuscular training is designed to help children master fundamental skills, improve movement mechanics, and gain confidence in their physical abilities while participating in a program that includes variety, progression, and proper recovery intervals (13,42,44). Integrative neuromuscular training programs utilize a variety of fundamental movements designed to enhance both health and skill-related fitness as well as to prepare safely children to be more physically active (Fig. 5) (10,18,41,44,45). It is likely that health benefits of exercise are evident even if improvements in body composition are not immediately evident in more athletic children (8).

The cornerstone of integrative neuromuscular training is age-appropriate education and instruction by qualified pediatric exercise specialists (Fig. 6). This type of training is designed to help children master fundamental skills, improve movement mechanics, and gain confidence in their physical abilities while participating in a program that includes variety, progression, and proper recovery intervals (13,43). Integrative neuromuscular training is vital for children...
whose cognitive and motor capabilities are highly “plastic” and amenable to age-appropriate interventions.

Recently researchers evaluated an integrative neuromuscular training program that was performed two times a week during the first 15 min of a second grade physical education class (10). This program consisted of body weight exercises that focused on the enhancement of muscular strength, muscular power, and fundamental movement skills and was found to be an effective and time-efficient addition to physical education as evidenced by improvements in health- and skill-related fitness measures in these children. High compliance and self-reported positive attitudes toward integrative neuromuscular training provided evidence of the feasibility and value of incorporation of integrative neuromuscular training into pediatric fitness programs (9). It appears therefore that the incorporation of integrative neuromuscular training programs is a cost-effective and time efficient method for enhancement of motor skills and promotion of PA in school-age children. Interestingly the 7-year-old women who underwent integrative neuromuscular training in addition to their standard physical education appeared to be particularly sensitive to the positive effects of this training regimen, which may be indicative of a potential sex-specific window for optimal implementation of the proposed interventional strategies (17).

Summary

A management team that includes professionals who understand the fundamental principles of pediatric exercise science and appreciate the physical and psychosocial uniqueness of children and adolescents may help to identify barriers to PA and provide access to activity-friendly environments. However in current child management models, physicians and pediatric exercise specialists have limited opportunity to work together in order to treat children with EDD (Fig. 6). The current health care system is designed to treat disease and does not provide opportunities for pediatric exercise specialists to collaborate with health care providers in order to enhance motor skills and promote PA as an ongoing lifestyle choice. Without a change in our current health care system, contemporary youth will remain likely on the current trajectory toward overweight, obesity, and associated health consequences.

Management approaches that link the resources of health care professionals and qualified pediatric exercise specialists may position us to circumvent effectively the “negative spiral of inactivity.” School-age children who participate in age-related PA programs designed and implemented by pediatric exercise specialists may help prevent the accumulation
of cardiovascular risk factors and pathological processes later in life (12,14,15). While limited from long-term outcome studies, current evidence supports the critical importance of primary prevention as part of a comprehensive approach to treating physical inactivity in children and promoting long-term health.

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