Title
Health-related physical fitness for children with cerebral palsy.

Journal
Journal of Child Neurology, 29(8)

Authors
Maltais, Désirée
Wiart, Lesley
Fowler, Eileen
et al.

Publication Date
2014-08-01

DOI
10.1177/0883073814533152

Published in final edited form as:
J Child Neurol. 2014 August ; 29(8): 1091–1100. doi:10.1177/0883073814533152.

Health-related physical fitness for children with cerebral palsy

Désirée B. Maltais, PhD, PT,
Department of Rehabilitation, *Université Laval*, and Centre for Interdisciplinary Research in Rehabilitation and Social Integration, Quebec City, QC, Canada

Lesley Wiart, PhD, PT,
Glenrose Rehabilitation Hospital, Alberta Health Services and Department of Physical Therapy, University of Alberta, Edmonton, AB, Canada

Eileen Fowler, PhD, PT,
Center for Cerebral Palsy, Orthopaedic Institute for Children, Department of Orthopaedic Surgery, Tarjan Center, University of California, Los Angeles, CA, USA

Olaf Verschuren, PhD, PT, and
Brain Center Rudolf Magnus and Center of Excellence for Rehabilitation Medicine, University Medical Center Utrecht and Rehabilitation Center De Hoogstraat, Utrecht, The Netherlands

Diane L. Damiano, PhD, PT
Rehabilitation Medicine Department, Clinical Center, National Institutes of Health, Bethesda, MD, USA

Désirée B. Maltais: Desiree.Maltais@rea.ulaval.ca; Lesley Wiart: lesley.wiart@ualberta.ca; Eileen Fowler: EFowler@mednet.ucla.edu; Olaf Verschuren: o.verschuren@dehoogstraat.nl; Diane L. Damiano: damianod@cc.nih.gov

Abstract

Low levels of physical activity are a global health concern for all children. Children with cerebral palsy have even lower physical activity levels than their typically developing peers. Low levels of physical activity, and thus an increased risk for related chronic diseases, are associated with deficits in health-related physical fitness. Recent research has provided therapists with the resources to effectively perform physical fitness testing and physical activity training in clinical settings with children who have cerebral palsy, although most testing and training data to date pertains to those who walk. Nevertheless, based on the present evidence, all children with cerebral palsy should engage, to the extent they are able, in aerobic, anaerobic and muscle strengthening activities. Future research is required to determine the best ways to evaluate health-related physical fitness in non-ambulatory children with cerebral palsy and foster long-term changes in physical activity behavior in all children with this condition.

Corresponding Author Address: Désirée B. Maltais, PhD, PT, CIRRIS-IRDPQ, Rm. H-1716, 525, boulevard Wilfrid-Hamel, Québec QC G1M 2S8, CANADA, Tel: 418-529-9141 ext. 6631, Fax: 418-529-3548, Desiree.Maltais@rea.ulaval.ca.

Author Contribution: All authors contributed to the conceptualization, writing and revising of this article. All authors also approved the final version.

Declaration of Conflicting Interests: None declared by any author.

Ethics approval: Not applicable.

Keywords

physical activity; physical fitness; cerebral palsy

Introduction

Low levels of physical activity are a worldwide threat to the health of children, including those with disabilities. For this reason, the World Health Organization recommends at least 60 minutes of moderate to vigorous physical activity per day including muscle and bone strengthening activities at least three days per week.[1] Some countries such as Canada also recommend limiting sedentary activity (e.g., screen time) to no more than 2 hours per day.[2] While there are no specific evidence-based physical activity guidelines for children with cerebral palsy, it is clear that they have lower levels of physical activity than their peers,[3] that they do not meet the physical activity guidelines,[3] and that their level of mobility limitation is negatively associated with their level of physical activity.[4] For example, school-aged children with cerebral palsy who are able to walk (with or without support) are, on average, 30% less active and about twice as sedentary as recommended.[3] Children with cerebral palsy who do not walk have lower levels of physical activity than those who do.[5,6]

Low levels of physical activity and thus an increased risk for related chronic diseases are associated with deficits in *health-related* physical fitness (attributes) such as cardiorespiratory endurance, muscle strength, anaerobic power and muscle endurance (anaerobic fitness), musculoskeletal flexibility and body composition.[7,8] The potential relevance of physical fitness to the overall health of young people with cerebral palsy has long been appreciated. In 1972, Robson[9] reviewed the fitness literature and rehabilitation practices for children with cerebral palsy, and concluded that the majority of children with cerebral palsy were inactive, creating lower levels of physical fitness than would be expected given their extent of physical disability. He suggested that this creates a downward spiral of reduced physical activity and associated reductions in fitness and motor function. He recommended that efforts be made to increase the physical fitness of children with cerebral palsy through targeted exercise and a general increase in opportunities for physical activity. Surprisingly, little new information about health-related physical fitness for those with cerebral palsy came to light during the two decades following Robson's recommendations. Since the end of the 20th century, however, evidence in this area, as measured by the number of publications related to physical fitness and cerebral palsy cited in PubMed, appears to be increasing greatly with time (Figure 1).

This article reviews the present state of evidence about three health-related physical fitness attributes for children with cerebral palsy: cardiorespiratory endurance, muscle strength and anaerobic fitness. Since accessible and enjoyable community physical activities may enhance the involvement of families with children with disabilities in their communities and promote long-term engagement in physical activity and lead to improved health-related fitness, this article also addresses some of the successes and challenges with integrating health-related fitness activity programs into community settings. Most of the literature applies to ambulatory children with cerebral palsy, those functioning in Gross Motor

Function Classification System levels I–III. When the literature relates to children who do not walk (i.e., those functioning in Gross Motor Function Classification System level IV or V), this is noted.

Cardiorespiratory Endurance

Overview

Cardiorespiratory endurance is the capacity of the body to perform physical activity that depends mainly on the aerobic or oxygen requiring energy systems. These are “aerobic” activities such as walking, running, cycling, swimming or propelling a wheelchair. The gold standard measure of cardiorespiratory endurance for children is the highest (peak) oxygen uptake value obtained during a graded exercise test, where the intensity of the aerobic activity systematically increases over time until the test is terminated, either because the individual can no longer maintain the desired exercise intensity or for safety reasons. Several treadmill, cycle and arm ergometer protocols, adapted to the child’s motor abilities, have been developed for children with cerebral palsy.[10] Shuttle run and shuttle wheel field tests, again adapted to the child’s motor abilities, have also been developed[11–14] For these field tests, children walk, run, or wheel back and forth, between two lines, a set distance apart, at increasingly faster speeds that are set by an auditory signal. The test ends when the child can no longer keep up the pace. Although no equations exist to predict peak oxygen uptake from these cerebral palsy specific field tests, an increase in the number of shuttle (stages) completed is considered to indicate an increase in cardiorespiratory fitness. Peak oxygen uptake can also be measured using these field tests if the child is connected to a portable (wearable) metabolic cart while he or she performs the test.

A recent systematic review of longitudinal studies with typically developing children[15] concluded that: 1) a higher level of cardiorespiratory endurance in childhood is associated with a healthier cardiovascular profile and with a lower risk of developing cardiovascular disease later on in life, and 2) an increase in cardiorespiratory endurance from childhood to adulthood is associated with a positive change in the cardiovascular risk profile. Children with cerebral palsy may have an even greater chance of developing cardiovascular disease than their typically developing peers since their cardiovascular endurance is generally lower than that of their typically developing peers.[16–20] Moreover, the deficit in cardiorespiratory endurance may also increase with age, at least for girls with cerebral palsy.[17] This deficit may also be greater for children with more severe mobility limitations.[19] Thus, these two groups may be at an even greater risk for cardiovascular disease later in life.

Based on their systematic review, Dencker et al. (2011)[21] concluded that there is a weak to moderate relationship between cardiorespiratory endurance and the level of habitual physical activity for typically developing children. Preliminary data also suggest that there is a weak to moderate relationship between cardiorespiratory endurance and the level of habitual physical activity for children with CP,[22] although this has yet to be confirmed in large scale studies. The lack of a strong relationship between physical activity and cardiorespiratory endurance is expected because physical activity is a complex behavior with many personal and environmental correlates other than cardio respiratory fitness.[23]

State of the Evidence

Given the importance of cardiorespiratory endurance for health, it is not surprising that the trainability of this attribute for children with cerebral palsy has been assessed over the years,[24–26] including in several relatively recent, randomized controlled trials.[27–30] These more recent studies have shown that aerobic exercise training using functional activities such as walking and running performed separately,[30] or in combination with strength training[27] or anaerobic training (sprinting type activities),[28] results in a significant increase in cardiorespiratory endurance.[27–30] In all of these studies the participants exercised at least 2–3 times per week for at least 30 minutes, at a moderate intensity of about 60–75% maximum heart rate[27–29] or 50% peak oxygen uptake.[30] Reported increases in cardiorespiratory endurance were: 23% for an 8 week intervention with young people in Gross Motor Function Classification System levels I and II;[30] 15% for 3 month intervention with those in Gross Motor Function Classification System levels II and III;[27] 40% for an 8 month intervention with children in Gross Motor Function Classification System levels I and II,[29] and 28% for a 9 month intervention with those likely in Gross Motor Function Classification System levels I–III and possibly level IV (study predates Gross Motor Function Classification System use).[28] These results suggest that greater gains in cardiorespiratory endurance may occur with longer interventions and for children with cerebral palsy who have greater mobility. Along with the positive changes to cardiorespiratory endurance, this type of exercise training also results in increases in mobility capacity.[27,29,30] This change is likely due to the nature of the activities (e.g. walking and running). Exercise training on a cycle ergometer, for example, had no clear effect on the mobility-related impairments and limitations of children with cerebral palsy.[31] Although 8–9 months of functional aerobic and anaerobic exercise may result in an immediate increase in their level of habitual physical activity,[28,29] much of the exercise training effects to cardiorespiratory fitness and mobility capacity are lost during the first 4 months after the training.[29] In other words, a prescribed exercise intervention alone does not appear to result in a lasting change in the physical activity behavior of children with cerebral palsy.

Muscle Strength

Overview

Muscle strength is classically defined as the maximum force that can be generated in a single isometric contraction of unrestrained duration. It is a key component of health-related physical fitness as a review of these attributes in youth showed that strength gains during childhood were inversely related to overall adiposity in adulthood.[15] As cerebral palsy results from an injury to motor regions of the developing brain, weakness is a primary impairment and there is strong evidence showing that children with cerebral palsy are significantly weaker than typically developing children.[32,33] In the spastic form of cerebral palsy, weakness and reduced selective motor control result specifically from damage to the corticospinal tracts, and impairment is most pronounced at distal joints.[33,34] Consequently, the ability to voluntarily recruit individual muscles is impaired and alternative motor pathways associated with synergistic limb flexion and extension may be strengthened. Secondary changes in the muscle such as atrophy, change in protein isoform composition and variability, fatty infiltration and alterations in the extracellular matrix, among others, may further affect force generation.[35,36] In muscles that exhibit contracture, increased sarcomere length and elevated collagen content of muscle bundles contribute to passive stiffness.[37] For individuals with cerebral palsy, the clearest relationship between muscle strength and physical activity is the positive relationship between muscle strength and mobility and related functions, including gait.[38] Weakness may also play a role in the observed decline in mobility in adults with cerebral palsy who do not exercise regularly.[39]

Clinically, strength tends to be tested by requesting and manually grading a maximal voluntary isometric contraction of the muscle groups at a particular joint assuming that antigravity movement in the intended direction is within full passive range. Hand-held dynamometers and isokinetic testing devices (the gold standard) are more objective methods that are typically used for research protocols. Measurement of maximum force generation at individual joints may be compromised by poor selective motor control depending on the task and position used for testing. Additionally, co-activation of antagonist muscle groups is excessive in children with cerebral palsy and contributes to reduced net joint production. For example, during maximum isometric quadriceps activation, the ratio of quadriceps to antagonistic semitendinosis muscle activity was 0.73 for children with cerebral palsy compared to 0.22 for children without cerebral palsy.[40] The ability to understand and follow directions is also required to obtain a valid measure of muscle strength. Thus, it may be difficult or impossible to directly measure muscle strength in very young children and those with intellectual disabilities or severe movement disorders who are not capable of providing an adequate level of cooperation or effort.

State of the Evidence

In the past decade, considerable research has been done to examine the efficacy of muscle strengthening interventions for children with cerebral palsy including randomized controlled trials, which are considered the highest quality design, and there has been an even greater number of systematic reviews. A recent systematic review[40] included seven studies that addressed efficacy or effectiveness of lower extremity strengthening interventions and concluded that there was sufficient evidence for short-term gains in the ability to produce force or torque but not for carryover to functional activities. The authors deemed it a “yellow-light” intervention that should “probably” be performed for children with cerebral palsy. It is important to examine the elements of randomized controlled trial protocols to determine factors that may elucidate optimal training parameters. Randomized controlled trial strength training protocols for children with cerebral palsy have varied in the type of exercise, duration and frequency.[41] Consistent with neural mechanisms and functional goals, exercise intervention randomized controlled trials with these children primarily have used functional exercises rather than providing resistance at a single joint. Resistive exercises were: sit to stand,[42,43] heel raises,[44] squats,[44,45] step ups,[44] lateral step ups,[42,45] stairs,[45] cycling,[34,45] half knee rises,[42] isotonic exercises with cuff weights,[45] weight lifting machines,[46] and leg press[42,46] All randomized controlled trials were of fairly short duration with a maximum of 12 weeks and the frequency was either two to three times per week. Age range spanned from four years of age into adulthood and Gross Motor Function Classification System levels were I–III.

It seems logical that if weakness is a cause of gait abnormalities in cerebral palsy, then increasing strength would also improve gait function. This has not been shown to be the case. While strength training, performed according to scientific principles, has been shown to increase strength in cerebral palsy, the *causal* effects of strength training programs on enhancing activity and participation including those components related to gait function, as defined in the International Classification of Functioning, Disability and Health,[47] are not as well established. Thus, it would seem that there are many considerations when designing and implementing a strength training program for individuals with cerebral palsy including intensity, duration, which muscles to strengthen, and how to strengthen them. Choice of muscles to be strengthened should depend on the functional motor goals of the individual child. However, care must be taken to not increase or cause muscle imbalance by solely targeting or inadvertently strengthening muscles that are already strong or shortened.[48] Functional strengthening, where the entire limb is loaded during a functional task, may fail to target the desired muscles sufficiently or inadvertently target others. The task may be dominated by non-targeted muscles that are already stronger so that the weaker targeted muscles do not benefit as intended. Interestingly, two recent randomized controlled studies[42,49] that employed this method demonstrated very small strength increases that seemed inconsistent with the program intensity and no functional benefits, suggesting that the non-specificity of functional strengthening may be a viable explanation for why these approaches are not very effective in conditions such as cerebral palsy where muscle imbalance is so prominent.

Given this concern, researchers have proposed that single joint exercise protocols be used in children with cerebral palsy. This recommendation is in accordance with the National Strength and Conditioning Association guidelines for typically developing children.[41] However, in children with cerebral palsy, this is complicated by the varying ability to isolate joint motion, especially at the ankle. Electrical stimulation may be an alternative or adjunct method to ensure that specific muscles are trained more effectively in this population. The extent to which changes in muscle pathology can be reversed is also still largely unknown; however, strengthening and electrical stimulation have both been shown to increase muscle size in cerebral palsy.[50–52]

Anaerobic fitness (anaerobic power and muscle endurance)

Overview

The term ‘anaerobic’ refers to the energy systems which do not require oxygen. In general, the higher the intensity and the shorter the duration, the greater is the demand on the anaerobic versus the aerobic (oxygen-requiring) energy systems. Anaerobic fitness can be broken into peak anaerobic power and muscular endurance. Peak anaerobic power is the maximal anaerobic adenosine triphosphate (ATP) per second yield by the whole organism, during short duration, maximal exercise,[53] like pulling to stand, jumping or sprinting. Muscular endurance is the ability to repeat or to maintain high-intensity muscular contractions over a short time (<2 min).[53]

Anaerobic fitness is relevant to health through its relationship to physical activity and mobility. Physical activity in children most often consists of “anaerobic” type activities, i.e., brief, intermittent bouts of intense movement that are commonly accumulated in the form of unstructured activities or free play over the course of the day.[54] These short bursts of activity are also characteristic of typical movement patterns seen in many structured activities. Thus, much of the structured or unstructured physical activity of children frequently relies on the anaerobic system. Anaerobic fitness (both peak anaerobic power and muscle endurance) increases with growth in typically developing children[55,56] and those with cerebral palsy.[57] Children with cerebral palsy, however, have lower anaerobic fitness levels than their typically developing peers.[19,58] Moreover, the deficit in anaerobic fitness increases with increasing motor impairment.[19] For children with cerebral palsy with more severe motor impairment, this deficit in anaerobic fitness (at least in muscle endurance) may not be stable and may actually increase with growth.[57]

The anaerobic fitness of children who are developing typically, as well as those with neurological conditions such as cerebral palsy, has been measured in the laboratory setting using the Wingate Anaerobic Test. The Wingate Anaerobic Test requires pedaling or arm cranking for 30 seconds at maximal speed against a constant, individually determined breaking force. The main Wingate Anaerobic Test variables are peak power (the highest mechanical power obtained during the test) and mean power (the average power over the entire 30 seconds). The latter is considered an indication of anaerobic muscular endurance. However, the necessary equipment for the Wingate Anaerobic Test is expensive, may require modification for use with children with cerebral palsy, and may not be readily accessible in most rehabilitation settings. Moreover, the Wingate Anaerobic Test does not measure anaerobic fitness during locomotor activities which are often the activities of interest when measuring physical fitness attributes in children with cerebral palsy.[59] The Muscle Power Sprint Test[60–62] was recently developed to address the limitations of the Wingate Anaerobic Test. This newer test requires no special equipment and can be used with children who can walk without support or with those who self-propel a manual wheelchair. The test consists of six (walking/running) or three (self-propelling a wheelchair) 15-m sprints, done as fast as possible, separated by 10-second rest periods. Power output is estimated for each sprint using the average velocity of the sprint and the child's body mass. Peak power is the highest value, derived from the sprint with the highest mean velocity. Mean power is the average power across the six sprints and is considered a measure of anaerobic muscle endurance. As with the Wingate test, higher values indicate greater anaerobic fitness.

State of the Evidence

To the best of our knowledge, van den Berg-Emons et al. (1998)[28] were the first to measure the effect of an intervention on the anaerobic fitness of children with cerebral palsy. These researchers found no training-related effects on either peak anaerobic power or muscle endurance following 9 months of an exercise intervention that was predominantly aerobic in nature. Anaerobic fitness, however, was measured using the laboratory based Wingate Anaerobic Test. More recently, the Muscle Power Sprint Test was used to examine the effect of an 8-month anaerobic and aerobic exercise intervention on anaerobic fitness.[29] The participants were children with cerebral palsy who were ambulatory without support (Gross Motor Function Classification System levels I and II). The main focus during the last 5 months of the intervention was anaerobic exercise. In this study, the authors reported an improvement in both anaerobic fitness (peak anaerobic power and muscle endurance) and cardiorespiratory endurance following the training. This later improvement is in accordance with studies with typically developing children, which have also shown an increase in cardiorespiratory endurance after anaerobic training.[63]

Implications for clinical practice

Clinicians can play an important role in promoting health-related physical fitness for individuals with cerebral palsy. A recent scoping review of exercise and nutrition programs for children with disabilities, including cerebral palsy, shows than many therapists are already integrating exercise training, including resistance training, into their treatment programs.[64] In addition, research evidence appears to have dispelled long-held clinical beliefs that muscle strengthening exacerbates spasticity.[65]

Clinician roles are expanding beyond traditional rehabilitation settings. For example, therapists are involved in facilitating the transition to community physical activity programs that can address health-related physical fitness.[66,67] Transitional fitness programs located in hospitals or specialized facilities for individuals with disabilities can be used to bridge the gap between health- and community-based programs.[67,68] Trained personnel can ensure individuals with disabilities and their families know how to access programs and supports available within their communities and that they are knowledgeable about effective and safe exercise. Individuals with cerebral palsy who may be significantly weak or deconditioned, who may have poor selective motor control, or who are unaccustomed to exercise, need to start with a lower initial intensity and increase slowly to optimize safety. Prior to using community facilities, individuals with cerebral palsy should learn how to use and adapt fitness equipment to their needs. Transitional programs can also establish formal linkages with community facilities and programs to increase knowledge of the supports required to make them accessible for individuals with disabilities.[69]

Increased recognition of the importance of health-related physical fitness for individuals with disabilities has led to the development of more practical resources for clinicians. Evidence-based information on health-related physical fitness, exercise training guidelines and suggestions for physical activity across the lifespan are easily accessible to rehabilitation clinicians at the National Center on Health, Physical Activity, and Disability website.[69] A new edition of the American College of Sports Medicine manual on exercise for people with chronic conditions also provides exercise testing and training information for individuals with cerebral palsy as well as physical activity suggestions across the lifespan and across the five Gross Motor Function Classification System levels.[70] Excellent guidelines for muscle strengthening for children, including loading, number of repetitions and frequency[71] are based on exercise physiology principles that can be applied to children with cerebral palsy. Strength training guidelines specific to cerebral palsy (Gross Motor Function Classification System levels I–III) are also available.[41]

Research to date has focused primarily on children in GMFCS levels I – III who have the ability to produce measureable force at the joint level and who are ambulatory. There is much less research available to guide clinicians in prescribing exercise for children who experience greater degrees of challenges with voluntary movement. In particular, the presence of involuntary dyskinetic movement disorders makes the use of standardized exercise protocols and strength assessment extremely challenging. For these children, activities that maximize gross motor function may be the only method to engage in physical activity. Active, active-assistive and resistive exercise can be elicited depending on the individual's capability. Overground cycling with an adapted tricycle is an enjoyable recreational activity that is commonly used in therapy and community settings. Adaptations to secure the foot to the pedal, support the trunk and enhance hand placement are available. Arm crank powered cycles may provide another option. Children with very little strength can contribute effort to the cycling motion using a tandem or side by side tricycle with another rider. In addition, stationary exercise for the upper and lower extremities can be performed using cycling ergometers that assist or resist exercise performance. Swimming may be a more feasible form of physical activity for children classified in Gross Motor Function Classification System Levels IV and V.[72] Specialized floatation devices can be utilized depending on individual needs. The faster the child moves their limbs, the greater the resistance. Although it is unknown what intensity of activity constitutes moderate to intensive exercise for children in Gross Motor Function Classification System levels IV and V, energy expenditure increases with Gross Motor Function Classification System level and therefore it is possible that these children may experience greater benefit from a lower intensity of physical activity.

Exercising programs in a wheelchair or on an exercise mat are other exercise options that do not involve specialized equipment or facilities. Mat "dancing" to music can be an enjoyable way to perform active movement in an individual or group setting. Being supine on a mat allows greater participation of trunk and extremity musculature during exercise and provides relief from skin pressure associated with prolonged wheelchair sitting. Regardless of the type of physical activity, individuals should be monitored closely for adverse effectives. A recent study reported a statistically significant increase in proximal lower extremity pain for non-ambulatory adults with CP following a three-month program that included upper and lower extremity resistive exercise.[73]

Research has yielded exercise-related tools that can be used by clinicians in a variety of settings. For example, until a few years ago, the evaluation of the cardiorespiratory endurance of children with cerebral palsy was limited in community settings because tests developed for typically developing children were not appropriate for children with cerebral palsy. Clinicians in typical rehabilitation settings and in the community can now evaluate cardiorespiratory endurance in youth with cerebral palsy using cerebral palsy-specific shuttle run tests, one for each of Gross Motor Function Classification System levels I-III,[12,14] and shuttle ride tests for children who self-propel a wheelchair.[11] The shuttle run test results of children at Gross Motor Function Classification System levels I and II can be compared to a reference data base of 306, 6–20 year old individuals with cerebral palsy.[13] Recent data have also shown that the level of participation in locomotor-related activities of daily living for children in Gross Motor Function Classification System levels I and II is associated more with their level of cardiorespiratory endurance, as evaluated using a cerebral palsy-specific shuttle run test, than with their ability to walk, as evaluated by the six-minute walk test.[74] Thus, clinicians can use cerebral palsy-specific shuttle run tests (and possibly shuttle ride tests) to evaluate locomotor-related cardiorespiratory endurance relevant to functioning in everyday life. Clinicians can also use heart rate monitors to directly measure maximal heart rate achieved during the shuttle run or ride test. Maximum heart rate can be used to determine the appropriate intensity of exercise training, as it has been shown that age-predicted maximal heart rate values are not valid for children with cerebral palsy.[75]

The move to inclusive, community-based programs

Access to community-based physical fitness programs and facilities for individuals with cerebral palsy will provide opportunities for maintaining a physically active lifestyle, which may be linked to enhanced functional mobility and overall health. Ando and colleagues (2000)[38] demonstrated that those with cerebral palsy who maintained an active lifestyle in adulthood were less likely to have a dramatic loss in mobility and Maltais et al.(2010)[76] showed that being physically active is positively related to the level of perceived health and maintenance of walking function for ambulatory adults with cerebral palsy. Despite the recognition that access to community-based physical activity programs is important for the long-term integration of physical activity into regular routines, the majority of research regarding physical activity for individuals with disabilities has been conducted in clinical and laboratory settings.[77] Establishing accessible health-related physical fitness programs in the community requires knowledge of the facilitators and barriers to access to these programs.

Common barriers to access to community-based fitness programs for individuals with disabilities include inaccessible physical environments (e.g. change rooms), lack of trained personnel and modified equipment, difficulty with accessing information about programs, inability to pay for membership fees, and transportation barriers.[78–80] Clearly, lack of accessible options in the community limits the potential for children with cerebral palsy to incorporate physical activity into their regular routines. It is notable that many of the barriers reported in the literature are environmental and modifiable. Advocacy for accessible community programs and facilities will likely raise awareness of the importance of ensuring individuals with disabilities have equal access to physical activity facilities and programs.[81] The development of strategic partnerships with health care providers and political systems may facilitate solutions to address access barriers.[82]

Assisting individuals with disabilities with community physical activity programs requires understanding of the factors that motivate children with disabilities to incorporate physical activity in their regular routines. Research in this area is only beginning to explore the relationship between the individual and their environment and how this interaction affects participation.[82] In a grounded theory study conducted to gain insight into the perspectives of adolescents with cerebral palsy on the factors that affect their quality of life,[83] the relationship between personal interests and opportunities to participate in valued activities was an important contributor to good quality of life. Therefore, individual preferences for activities, program formats, settings, group or individual activities must be considered if those with disabilities are going to be successful in engaging in physical activity behaviors that are enjoyable and sustainable for the long-term. Personal preferences for the format of physical activity programs or unstructured physical activity will likely vary depending upon personal activity preferences, ability level and age of the child and the outcomes that are most important to families. For example, parents who perceive their children do not have adequate opportunities for socialization at school may prefer group activities.[78] Others may prefer individual programs[82] or engaging in physical activity outside of a structured program. Some children may enjoy a short-term, high intensity training program because it can offer the necessary variation and it can also provide more immediate feedback on performance since identifiable short-term gains can be linked with personal fitness goals. This type of physical activity is also recommended to help ensure the optimal health of children.[2,84] Based on these reasons, **we recommend considering anaerobic and muscle strengthening activities as part of the physical activity repertoire of children with cerebral palsy in addition to aerobic activities.** There is no 'one size fits all' physical activity repertoire, so ensuring a variety of options for community-based structured and unstructured physical activity may be needed to encourage a good fit between individual preferences, opportunities, and the kinds of activities that are recommended for health reasons.

Implications for future research

While this paper has focused on health-related physical fitness, the benefits of physical activity go beyond fitness or related outcomes typically evaluated in rehabilitation research. For example, community-based physical fitness programs provide opportunities for social interaction and the inclusion of children with disabilities in their communities.[85] Families may place high value on physical activities that provide opportunities for socialization and improved psychosocial well-being.[78] Additional research is needed to explore the effects of physical fitness programs on these outcomes. Research is also needed on the effectiveness of strategies to reduce barriers to physical activity for individuals with disabilities that is informed by theories of behavior change.[86] While there has been some initial exploration of the linkages between stage of change (i.e., pre-intention, intention or action stage) and perceived barriers and facilitators to physical activity with parents of children with cerebral palsy,[86] additional research is required to explore how therapists can enhance self-efficacy regarding physical activity. Individualized coaching that addresses specific barriers may be effective in encouraging behaviour change than general approaches that espouse the beneifits of physical activity.[86]

Evidence on the benefits of cardiorespiratory endurance exercise is clear. While initial research on the benefits of anaerobic exercise for children with cerebral palsy appears promising, additional information on its effectiveness is warranted. Currently, anaerobic exercise is not commonly used clinically with individuals with cerebral palsy. This is surprising since anaerobic power is impaired in children with cerebral palsy, seems to benefit from training, and is related to gross motor skill performance. Conversely, muscle strengthening is used routinely in clinical practice, and while it is related to health, more research is needed to evaluate the effectiveness of targeted muscle strengthening strategies for improving functional outcomes related to mobility. The highest research and clinical priorities may be to establish proactive strategies to promote muscle health early in development that are maintained as children with cerebral palsy grow and develop throughout the lifespan, and the identification of alternative treatment strategies for current ones that may exacerbate weakness (e.g., botulinum toxin or muscle-tendon lengthening). Research should also relate muscle integrity to training responsiveness, and more basic research into the factors that precipitate mal-adaptive changes in muscle tissue in cerebral palsy and how these may potentially be reversed is also warranted.

Longitudinal studies will provide important information about the long-term effects of physical fitness and physical activity on health, including 1) who is at greatest risk for later health problems related to low levels of physical activity and fitness, 2) which interventions will lead to meaningful and sustainable health-related results over the long term, and 3) how these interventions vary depending on the Gross Motor Function Classification System level, and 4) the long term health effects of reducing sedentary behavior or increasing moderate and vigorous physical activity (or both) across the spectrum of Gross Motor Function Classification System levels.[70,87] Greater emphasis on the development of valid and reliable health-related physical fitness tests for non-ambulatory individuals with cerebral palsy (Gross Motor Function Classification System IV and V) will facilitate the inclusion of this group in clinical intervention programs.

While there has been significant attention paid to the adverse health effects of sedentary behaviour over the last decade,[88] this approach has only recently been explored in children with cerebral palsy.[87,89] Decreasing sedentary behaviour may provide a viable alternative to intensive exercise for children with cerebral palsy particularly for non-ambulatory children or for families who find it challenging to integrate regular physical activity into their regular routines. However, research in this area is in the preliminary phases and there is a great deal to be learned about measurement of sedentary behaviour and the effects of interventions on functional abilities and health outcomes[89] before this approach can be confidently integrated into clinical practice.

Summary

Health-related physical fitness refers to a set of attributes that may influence health because they are associated with an increased risk of chronic diseases related to low levels of physical activity. The health-related physical fitness components that have been studied the most for children with cerebral palsy are cardiorespiratory endurance, muscle strength and anaerobic fitness. Much of the research, however, has been done with children with cerebral palsy who walk, either with or without assistive devices. Although these children have reduced fitness across the three attributes, fitness in each area can improve in the short term with exercise training. The extent to which improvements in fitness are associated with improvements in mobility, however, is not always clear and may be related to the type of exercise training that is undertaken. Simple and easy to use tests to measure these three fitness attributes for ambulatory children with cerebral palsy (and in some case those in a wheelchair) and resources to guide the design of effective exercise (fitness) training programs are now available to clinicians. As a result, exercise training is increasingly used as an intervention tool with this group. Very little, however, is known about how to maintain improvements in health-related fitness over the long term. This requires a long term change in physical activity behavior and is probably best achieved through sustainable, structured and unstructured physical activity performed in a child's typical environments (home, school, community). Future research will provide much needed information on the optimal ways to foster this behavior change. Research with children with cerebral palsy who are unable to walk is also required to better understand evaluation, implementation and maintenance of physical activity and health-related fitness.

Acknowledgments

The authors would like to acknowledge Amy McPherson for her thoughtful comment on this manuscript.

Funding: This work was supported in part by the intramural research program of the NIH Clinical Center.

References

1. World Health Organization. [Accessed March 6, 2014] Global recommendations on physical activity for health. 2010. http://whqlibdoc.who.int/publications/2010/9789241599979_eng.pdf?ua=1
2. Canadian Society for Exercise Physiology. Physical Activity Guidelines for Children and Adolescents. 2013. [Accessed November 12, 2013]
3. Carlon SL, Taylor NF, Dodd KJ, Shields N. Differences in habitual physical activity levels of young people with cerebral palsy and their typically developing peers: A systematic review. Disability and Rehabilitation. 2013; 35(8):647–655. [PubMed: 23072296]
4. Bjornson KF, Belza B, Kartin D, et al. Ambulatory physical activity performance in youth with cerebral palsy and youth who are developing typically. Physical Therapy. 2007; 87(3):248–257. [PubMed: 17244693]
5. Gorter JW, Noorduyn SG, Obeid J, Timmons BW. Accelerometry: a feasible method to quantify physical activity in ambulatory and nonambulatory adolescents with cerebral palsy. International Journal of Pediatrics. 2012:329284. [PubMed: 22792119]
6. Maher CA, Williams MT, Olds T, Lane AE. Physical and sedentary activity in adolescents with cerebral palsy. Developmental Medicine & Child Neurology. 49(6):450–457. [PubMed: 17518932]
7. Bouchard, C.; Shephard, RJ. Physical activity, fitness and health: the model and key concepts. In: Bouchard, C.; Shephard, RJ.; Stephen, T., editors. Physical activity, fitness and health: international proceedings and consensus statement. Champaign, IL: Human Kinetics; 1994.
8. Pate R. The evolving definition of physical fitness. Quest. 1988; 40:174–179.
9. Robson P. Cerebral palsy and physical fitness. Developmental Medicine and Child Neurology. 1972; 14(6):811–813. [PubMed: 4643441]
10. Wright, FV.; Maltais, DB.; Sanders, H.; Burtner, PA. Neuromusculoskeletal and movement related functions. In: Majnemer, A., editor. Measures for Children with Developmental Disabilities: An ICF-CY Approach. London: MacKeith Press; 2012. p. 192-230.
11. Verschuren O, Zwinkels M, Ketelaar M, et al. Reproducibility and validity of the 10-meter shuttle ride test in wheelchair-using children and adolescents with cerebral palsy. Physical Therapy. 2013; 93(7):967–974. [PubMed: 23580630]
12. Verschuren O, Bosma L, Takken T. Reliability of a shuttle run test for children with cerebral palsy who are classified at Gross Motor Function Classification System level III. Developmental Medicine and Child Neurology. 2011; 53(5):470–472. [PubMed: 21309762]
13. Verschuren O, Bloemen M, Kruitwagen C, Takken T. Reference values for aerobic fitness in children, adolescents, and young adults who have cerebral palsy and are ambulatory. Physical Therapy. 2010; 90(8):1148–1156. [PubMed: 20558568]
14. Verschuren O, Takken T, Ketelaar M, et al. Reliability and validity of data for 2 newly developed shuttle run tests in children with cerebral palsy. Physical Therapy. 2006; 86(8):1107–1117. [PubMed: 16879044]

15. Ruiz JR, Castro-Piñero J, Artero EG, et al. Predictive validity of health-related fitness in youth: A systematic review. British Journal of Sports Medicine. 2009; 43(12):909–923. [PubMed: 19158130]
16. Verschuren O, Takken T. Aerobic capacity in children and adolescents with cerebral palsy. Research in Developmental Disabilities. 2010; 31(6):1352–1357. [PubMed: 20674266]
17. Dallmeijer AJ, Brehm MA. Physical strain of comfortable walking in children with mild cerebral palsy. Disability and Rehabilitation. 2011; 33(15–16):1351–1357. [PubMed: 21073360]
18. Lundberg A. Longitudinal study of physical working capacity of young people with spastic cerebral palsy. Developmental Medicine and Child Neurology. 1984; 26(3):328–334. [PubMed: 6734948]
19. Balemans ACJ, Van Wely L, De Heer SJA, et al. Maximal aerobic and anaerobic exercise responses in children with cerebral palsy. Medicine and Science in Sports and Exercise. 2013; 45(3):561–568. [PubMed: 23034639]
20. Hoofwijk M, Unnithan V, Bar Or O. Maximal treadmill performance of children with cerebral palsy. Pediatric Exercise Science. 1995; 7:305–313.
21. Dencker M, Andersen LB. Accelerometer-measured daily physical activity related to aerobic fitness in children and adolescents. Journal of Sports Sciences. 2011; 29(9):887–895. [PubMed: 21604226]
22. Maltais DB, Pierrynowski MR, Galea VA, Bar-Or O. Physical activity level is associated with the O2 cost of walking in cerebral palsy. Medicine and Science in Sports and Exercise. 2005; 37(3): 347–353. [PubMed: 15741829]
23. Sallis JF. Epidemiology of physical activity and fitness in children and adolescents. Critical reviews in food science and nutrition. 1993; 33(4–5):403–408. [PubMed: 8357503]
24. Lundberg A, Ovenfors CO, Saltin B. Effect of physical training on school-children with cerebral palsy. Acta Paediatrica Scandinavica. 1967; 56(2):182–188. [PubMed: 6049800]
25. Berg K. Effect of physical training of school children with cerebral palsy. Acta Paediatrica Scandinavica. 1970; 56:182–188.
26. Bar Or O, Inbar O, Spira R. Physiological effects of a sports rehabilitation program on cerebral palsied and post poliomyelitic adolescents. Medicine and Science in Sports and Exercise. 1976; 8(3):157–161.
27. Unnithan VB, Katsimanis G, Evangelinou C, et al. Effect of strength and aerobic training in children with cerebral palsy. Medicine and Science in Sports and Exercise. 2007; 39:1902–1090. [PubMed: 17986896]
28. Van Den Berg-Emons RJ, Van Baak MA, Speth L, Saris WH. Physical training of school children with spastic cerebral palsy: Effects on daily activity, fat mass and fitness. International Journal of Rehabilitation Research. 1998; 21(2):179–194. [PubMed: 9924680]
29. Verschuren O, Ketelaar M, Gorter JW, et al. Exercise training program in children and adolescents with cerebral palsy: A randomized controlled trial. Archives of Pediatrics and Adolescent Medicine. 2007; 161(11):1075–1081. [PubMed: 17984410]
30. Nsenga Leunkeu A, Shephard RJ, Ahmaidi S. Six-minute walk test in children with cerebral palsy gross motor function classification system levels I and II: Reproducibility, validity, and training effects. Archives of Physical Medicine and Rehabilitation. 2012; 93(12):2333–2339. [PubMed: 22721868]
31. Fowler EG, Knutson LM, DeMuth SK, et al. Pediatric endurance and limb strengthening (PEDALS) for children with cerebral palsy using stationary cycling: A randomized controlled trial. Physical Therapy. 2010; 90(3):367–381. [PubMed: 20093327]
32. Eek MN, Beckung E. Walking ability is related to muscle strength in children with cerebral palsy. Gait and Posture. 2008; 28(3):366–371. [PubMed: 18595712]
33. Wiley ME, Damiano DL. Lower-extremity strength profiles in spastic cerebral palsy. Developmental Medicine and Child Neurology. 1998; 40(2):100–107. [PubMed: 9489498]
34. Fowler EG, Staudt LA, Greenberg MB. Lower-extremity selective voluntary motor control in patients with spastic cerebral palsy: Increased distal motor impairment. Developmental Medicine and Child Neurology. 2010; 52(3):264–269. [PubMed: 20089048]

35. Peterson MD, Gordon PM, Hurvitz EA, Burant CF. Secondary muscle pathology and metabolic dysregulation in adults with cerebral palsy. American Journal of Physiology - Endocrinology and Metabolism. 2012; 303(9):E1085–E1093. [PubMed: 22912367]

36. Rose J, McGill KC. Neuromuscular activation and motor-unit firing characteristics in cerebral palsy. Developmental Medicine and Child Neurology. 2005; 47(5):329–336. [PubMed: 15892375]

37. Smith LR, Lee KS, Ward SR, et al. Hamstring contractures in children with spastic cerebral palsy result from a stiffer extracellular matrix and increased in vivo sarcomere length. Journal of Physiology. 2011; 589(10):2625–2639. [PubMed: 21486759]

38. Ando N, Ueda S. Functional deterioration in adults with cerebral palsy. Clinical Rehabilitation. 2000; 14(3):300–306. [PubMed: 10868725]

39. Damiano DL, Abel MF. Functional outcomes of strength training in spastic cerebral palsy. Archives of Physical Medicine and Rehabilitation. 1998; 79(2):119–125. [PubMed: 9473991]

40. Novak I, McIntyre S, Morgan C, et al. A systematic review of interventions for children with cerebral palsy: State of the evidence. Developmental Medicine and Child Neurology. 2013; 55(10):885–910. [PubMed: 23962350]

41. Verschuren O, Ada L, Maltais DB, et al. Muscle strengthening in children and adolescents with spastic cerebral palsy: Considerations for future resistance training protocols. Physical Therapy. 2011; 91(7):1130–1139. [PubMed: 21546567]

42. Scholtes VA, Becher JG, Comuth A, et al. Effectiveness of functional progressive resistance exercise strength training on muscle strength and mobility in children with cerebral palsy: A randomized controlled trial. Developmental Medicine and Child Neurology. 2010; 52(6):e107–e113. [PubMed: 20132136]

43. Liao HF, Liu YC, Liu WY, Lin YT. Effectiveness of Loaded Sit-to-Stand Resistance Exercise for Children With Mild Spastic Diplegia: A Randomized Clinical Trial. Archives of Physical Medicine and Rehabilitation. 2007; 88(1):25–31. [PubMed: 17207671]

44. Dodd KJ, Taylor NF, Graham HK. A randomized clinical trial of strength training in young people with cerebral palsy. Developmental Medicine and Child Neurology. 2003; 45(10):652–657. [PubMed: 14515935]

45. Lee JH, Sung IY, Yoo JY. Therapeutic effects of strengthening exercise on gait function of cerebral palsy. Disability and Rehabilitation. 2008; 30(19):1439–1444. [PubMed: 19230216]

46. Taylor NF, Dodd KJ, Baker RJ, et al. Progressive resistance training and mobility-related function in young people with cerebral palsy: A randomized controlled trial. Developmental Medicine and Child Neurology. 2013; 55(9):806–812. [PubMed: 23789741]

47. World Health Organization. International Classification of Functioning, Disability and Health. Geneva: World Health Organization; 2001.

48. Damiano DL, Arnold AS, Steele KM, Delp SL. Can strength training predictably improve gait kinematics? A pilot study on the effects of hip and knee extensor strengthening on lower-extremity alignment in cerebral palsy. Physical Therapy. 2010; 90(2):269–279. [PubMed: 20022999]

49. Scholtes VA, Becher JG, Janssen-Potten YJ, et al. Effectiveness of functional progressive resistance exercise training on walking ability in children with cerebral palsy: a randomized controlled trial. Research in Developmental Disabilities. 2012; 33(1):181–188. [PubMed: 22093663]

50. McNee AE, Gough M, Morrissey MC, Shortland AP. Increases in muscle volume after plantarflexor strength training in children with spastic cerebral palsy. Developmental Medicine and Child Neurology. 2009; 51(6):429–435. [PubMed: 19170722]

51. Damiano DL, Prosser LA, Curatalo LA, Alter KE. Muscle plasticity and ankle control after repetitive use of a functional electrical stimulation device for foot drop in cerebral palsy. Neurorehabilitation and Neural Repair. 2013; 27(3):200–207. [PubMed: 23042834]

52. Moreau NG, Holthaus K, Marlow N. Differential adaptations of muscle architecture to high-velocity versus traditional strength training in cerebral palsy. Neurorehabilitation and Neural Repair. 2013; 27(4):325–334. [PubMed: 23292847]

53. Green S. A definition and systems view of anaerobic capacity. European Journal of Applied Physiology and Occupational Physiology. 1994; 69(2):168–173. [PubMed: 7805673]

54. Bailey RC, Olson J, Pepper SL, et al. The level and tempo of children's physical activities: An observational study. Medicine and Science in Sports and Exercise. 1995; 27(7):1033–1041. [PubMed: 7564970]
55. Van Praagh E, Doré E. Short-term muscle power during growth and maturation. Sports Medicine. 2002; 32(11):701–728. [PubMed: 12196031]
56. Rowland, JL. Children's exercise physiology. 2. Champaign, IL: Human Kinetics; 2005. Short-burst anaerobic fitness; p. 166-180.
57. Verschuren O, Maltais DB, Douma-Van Riet D, et al. Anaerobic performance in children with cerebral palsy compared to children with typical development. Pediatric Physical Therapy. 2013; 25(4):409–413. [PubMed: 23974826]
58. Parker DF, Carriere L, Hebestreit H, Bar-Or O. Anaerobic endurance and peak muscle power in children with spastic cerebral palsy. American Journal of Diseases of Children. 1992; 146(9): 1069–1073. [PubMed: 1514554]
59. Bar-Or O. The Wingate anaerobic test: An update on methodology, reliability and validity. Sports Medicine. 1987; 4(6):381–394. [PubMed: 3324256]
60. Verschuren O, Takken T, Ketelaar M, et al. Reliability for running tests for measuring agility and anaerobic muscle power in children and adolescents with cerebal palsy. Pediatric Physical Therapy. 2007; 19(2):108–115. [PubMed: 17505287]
61. Verschuren O, Zwinkels M, Obeid J, et al. Reliability and validity of short-term performance tests for wheelchair-using children and adolescents with cerebral palsy. Developmental Medicine and Child Neurology. 2013
62. Verschuren O, Bongers BC, Obeid J, et al. Validity of the muscle power sprint test in ambulatory youth with cerebral palsy. Pediatric Physical Therapy. 2013; 25(1):25–28. [PubMed: 23288003]
63. Williams CA, Armstrong N, Powell J. Aerobic responses of prepubertal boys to two modes of training. British Journal of Sports Medicine. 2000; 34(3):168–173. [PubMed: 10854015]
64. McPherson A, Keith R. Obesity prevention for children with physical disabilities: A scoping review of physical activity and nutrition interventions. Disability and Rehabilitation. in press.
65. Damiano DL. Rehabilitative therapies in cerebral palsy: The good, the not as good, and the possible. Journal of Child Neurology. 2009; 24(9):1200–1204. [PubMed: 19525491]
66. Kotte EMW, Winkler AMF, Takken T. Fitkids exercise therapy program in the Netherlands. Pediatric Physical Therapy. 2013; 25(1):7–13. [PubMed: 23208224]
67. Rimmer JH, Henley KY. Building the crossroad between inpatient/outpatient rehabilitation and lifelong community-based fitness for people with neurologic disability. Journal of Neurologic Physical Therapy. 2013; 37(2):72–77. [PubMed: 23681276]
68. Rimmer JH. Getting beyond the plateau: Bridging the gap between rehabilitation and community-based exercise. PM and R. 2012; 4(11):857–861. [PubMed: 23174550]
69. National Center on Health Physical Activity, and Disability. National Center on Health, Physical Activity, and Disability. 2013. http://www.ncpad.org/
70. Maltais, D. Cerebral palsy. ACSM's Exercise Management for Persons with Chronic Conditions. 4. American College of Sports Medicine; 2013.
71. Small EW, McCambridge MT, Benjamin HJ, et al. Strength training by children and adolescents. Pediatrics. 2008; 121(4):835–840. [PubMed: 18381549]
72. Kelly M, Darrah J. Aquatic exercise for children with cerebral palsy. Developmental Medicine and Child Neurology. 2005; 47(12):838–842. [PubMed: 16288676]
73. Vogtle LK, Malone LA, Azuero A. Outcomes of an exercise program for pain and fatigue management in adults with cerebral palsy. Disability and Rehabilitation. 2013:1–8. (e-pub ahead of print).
74. Ferland C, Moffet H, Maltais DB. Locomotor Tests predict community mobility in children and youth with cerebral palsy. Adapted Physical Activity Quarterly. 2012; 29(3):266–277. [PubMed: 22811566]
75. Verschuren O, Maltais DB, Takken T. The 220-age equation does not predict maximum heart rate in children and adolescents. Developmental Medicine and Child Neurology. 2011; 53(9):861–864. [PubMed: 21569015]

76. Maltais DB, Dumas F, Boucher N, Richards CL. Factors related to physical activity in adults with cerebral palsy may differ for walkers and nonwalkers. American Journal of Physical Medicine and Rehabilitation. 2010; 89(7):584–597. [PubMed: 20463567]
77. Rimmer JA, Rowland JL. Physical activity for youth with disabilities: A critical need in an underserved population. Developmental Neurorehabilitation. 2008; 11(2):141–148. [PubMed: 18415819]
78. Wiart L, Darrah J, Kelly M, Legg D. Community fitness programs: What is available for children and youth with motor disabilities and what do parents want? Physical and Occupational Therapy in Pediatrics. in press.
79. Verschuren O, Wiart L, Hermans D, Ketelaar M. Identification of facilitators and barriers to physical activity in children and adolescents with cerebral palsy. Journal of Pediatrics. 2012; 161(3):488–494. [PubMed: 22494875]
80. Rimmer JH, Riley B, Wang E, et al. Physical activity participation among persons with disabilities: Barriers and facilitators. American Journal of Preventive Medicine. 2004; 26(5):419–425. [PubMed: 15165658]
81. Murphy NA, Carbone PS. Promoting the participation of children with disabilities in sports, recreation, and physical activities. Pediatrics. 2008; 121(5):1057–1061. [PubMed: 18450913]
82. Shimmell LJ, Gorter JW, Jackson D, et al. “It’s the participation that motivates him”: Physical activity experiences of youth with cerebral palsy and their parents. Physical and Occupational Therapy in Pediatrics. 2013; 33(4):405–420. [PubMed: 23663137]
83. Shikako-Thomas K, Lach L, Majnemer A, et al. Quality of life from the perspective of adolescents with cerebral palsy: “I just think I’m a normal kid, I just happen to have a disability”. Quality of Life Research. 2009; 18(7):825–832. [PubMed: 19548117]
84. Centres of Disease Control and Prevention. Physical Activity Guidelines for children and adolescents. 2013. [Accessed November 12, 2013]
85. George CL, Oriel KN, Blatt PJ, Marchese V. Impact of a community-based exercise program on children and adolescents with disabilities. Journal of Allied Health. 2011; 40(4):e55–e60. [PubMed: 22138879]
86. Verschuren O, Wiart L, Ketelaar M. Stages of change in physical activity behavior in children and adolescents with cerebral palsy. Disability and Rehabilitation. 2013; 35(19):1630–1635. [PubMed: 23336120]
87. Verschuren O, Darrah J, Novak I, et al. Health-enhancing physical activity in children with cerebral palsy: more of the same is not enough. Physical Therapy. 94(2):297–305. [PubMed: 24092902]
88. Tremblay MS, LeBlanc AG, Kho ME, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. International Journal of Behavioral Nutrition & Physical Activity. 8:98.
89. Innes J, Darrah J. Sedentary behavior: Implications for children with cerebral palsy. Pediatric Physical Therapy. 25(4):402–408. [PubMed: 23900023]

Key Take-Home Messages

- Health-related physical fitness has long been an important consideration for children with cerebral palsy, but little evidence was available in the past to guide therapists in using fitness related interventions;
- Based on present evidence, we recommend considering anaerobic and muscle strengthening activities as well as aerobic activities as part of the physical activity repertoire of children with cerebral palsy;
- Recent research has provided therapists with the resources to effectively perform physical fitness testing and physical activity training in the clinic setting with ambulatory children with cerebral palsy and in some cases with children with cerebral palsy who do not walk but who can propel a manual wheelchair;
- Future research is required to help therapists determine the best ways to foster long term changes in physical activity behavior that will sustain life-long optimal physical fitness levels and optimal health as well as optimal inclusion;
- Future research is also required to provide therapists with physical fitness testing and training resources for children with cerebral palsy who do not walk.

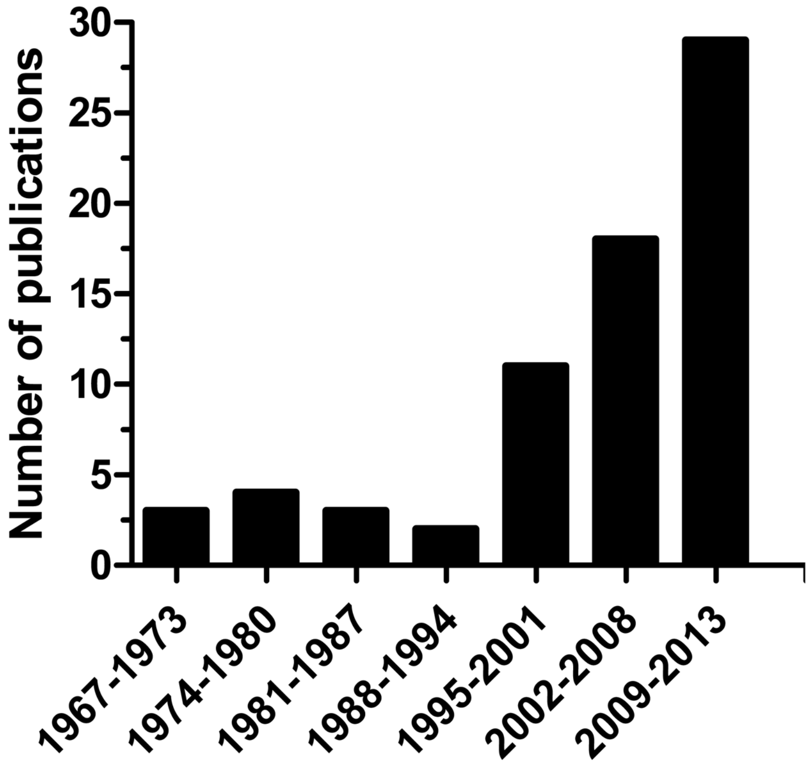

Figure 1.

The numbers of publications containing the key words "physical fitness" and "cerebral palsy" indexed by Pubmed per 7 year time span (with the exception of the last time span). This number appears to be increasing since the end of the 20th century.