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Exercise and Physical Activity Recommendations for People with Cerebral Palsy

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Abstract

Physical activity (PA) and its promotion, as well as the avoidance of sedentary behaviour play important roles in health promotion and prevention of lifestyle-related diseases. Guidelines for **typically developing** youth and adults published by the World Health Organization and American College of Sports Medicine are available. However, detailed recommendations for PA and sedentary behaviour have not been established for children, adolescents and adults with cerebral palsy (CP). This paper presents the first CP-specific PA and exercise recommendations. The recommendations are based on (1) a comprehensive review and analysis of the literature, (2) expert opinion and (3) extensive clinical experience. The evidence supporting these recommendations are based on randomized controlled trials and observational studies involving children, adolescents and adults with CP, and buttressed by the previous guidelines for the general population. These recommendations may be used to guide healthcare providers on exercise and daily PA prescription for individuals with CP.

Introduction

Many children, adolescents and adults with cerebral palsy (CP) have reduced cardiorespiratory endurance (the capacity of the body to perform physical activity that

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depends mainly on the aerobic or oxygen-requiring energy systems), muscle strength and habitual physical activity (PA) participation.[1–8] Reduced cardiorespiratory endurance and muscular weakness each pose significant risk for negative health outcomes and early, cardiovascular- and all-cause mortality.[9–12] Because persons with CP have lower levels of health-related fitness (muscle strength and cardiorespiratory endurance) and reduced levels of PA, they are at higher risk for developing metabolic and cardiovascular diseases. This has been shown by increased cardiometabolic risk factors, including hypertension, cholesterol, HDL-C, visceral adipose tissue and obesity in adults with CP.[13–16] Moreover, we have recently shown that in a population-representative sample of adults with CP, there were substantially increased estimates of chronic diseases, such as diabetes, asthma, hypertension and other cardiovascular conditions, stroke, joint pain, and arthritis.[17]

Globally, there is a need to encourage greater participation in PA, consistent with guidelines, in order to achieve higher fitness levels, decrease disease risk factors and reduce secondary complications such as early functional loss.[18] The importance of PA and its promotion as well as the avoidance of sedentary behaviour is indisputable. Comprehensive clinical outpatient programs, such as cardiac rehabilitation, have proven to be cost-effective and worthwhile in helping patients manage their risk for cardiovascular disease and other chronic diseases, but have done so by focusing predominantly on exercise rather than the avoidance of sedentary behaviour.[19] Physical activity is necessary for the optimal physical, emotional, and psychosocial development of all children. However, many parents, patients, caregivers, educators, and clinicians have questions regarding appropriate levels of PA for individuals with CP. Healthcare providers can therefore play an instrumental role in the promotion of PA by encouraging people with CP and families to integrate it into daily life.

They can also provide education regarding the role of PA to augment traditional therapy and how it can be used to maintain physical health into and throughout adulthood. Indeed, PA participation can gradually replace the therapies that were such an important part of the children and adolescents' lives, especially as they transition into adulthood. Lifestyle PA counselling should therefore be a priority during every visit with a healthcare professional. Healthcare professionals should encourage the patient (and their caregivers) to ask questions about their PA levels and should provide specific counselling to assist with accessibility strategies for PA as well as suggestions for activity/exercise prescription.

Detailed recommendations regarding minimum standards for PA and sedentary behaviour have not been established for children, adolescents and adults with CP. However, global guidelines for typically developing youth and adults have been published by the World Health Organization (WHO).[20] To a large extent, these are based on expert recommendations rather than definitive scientific evidence, and suggest that children and adolescents should accumulate at least 60 min of moderate-to-vigorous intensity PA per day.[21] Moreover, recommendations suggest that sedentary behavior should be limited to a daily maximum of 2 hours.[22] For adults, the recommendations call for a minimum of 30 min of moderate-to-vigorous intensity PA per day,[23] and that the amount of sedentary behaviour should be minimised as much as possible. These general recommendations, however, do not include specific suggestions for target groups like people with CP.

The focus of this paper is on PA and exercise for improving health and fitness in CP, with specific emphasis on cardiorespiratory endurance, muscle strengthening and reduction of sedentary behaviour. The data supporting these recommendations are based on previous studies involving children, adolescents and adults with CP, and are provided in context with the guidelines for the general population. The benefits of various approaches for initiating and administering a progressive activity program for persons with CP, classified at GMFCS level IV and V, have not been systematically evaluated. Based on a combination of scientific evidence, expert opinion and clinical experience, we aim to highlight the complex and multidimensional aspects of PA and exercise to establish CP-specific recommendations.

Cardiorespiratory Endurance Training

Given the well-established link between cardiorespiratory endurance and overall health, it is not surprising that the adaptive-response of this fitness component has been assessed in children, adolescents and adults with CP. To provide the highest level of evidence, we carried out a comprehensive review including only randomized controlled trials (RCTs), in which participants received cardiorespiratory endurance training versus placebo or no intervention. This resulted in 5 randomized controlled trials **(see** Table 1).[24–28] These studies collectively demonstrate that aerobic exercise training *can* lead to significant increases in cardiorespiratory endurance among individuals with CP.

An understanding of existing evidence-based intervention approaches is essential for the development of effective exercise programs for people with CP. Unfortunately, to date these exist only for children, adolescents and adults who are typically developing. Equally important is a thorough familiarity for the unique physical attributes and limitations of people with CP. To be able to develop universally-accepted exercise prescription guidelines for children and adults with CP, we have relied on a basic and well-accepted framework of prescription nomenclature to operationalize the exercise variables from published RCTs in this population, including (1) Frequency, (2) Intensity, (3) Time, and (4) Type. We have evaluated the extent to which recent training intervention studies were consistent with current recommendations related to cardiorespiratory (“aerobic”) exercise as provided by the ACSM.[29] Briefly, these guidelines recommend a frequency of 5 days/week of moderate exercise or 3 days/week of vigorous exercise. For typically developing persons who are deconditioned, the recommendation is to include light- to moderate-intensity exercise, and moderate and vigorous intensity. The recommendation is 20–60 min of continuous and rhythmic moderate or vigorous exercises that involve major muscle groups.

Frequency

Training frequency refers to the number of exercise sessions per week. All five RCTs[24–28] incorporated a training frequency of two to four sessions per week. For typically developing children, adolescents and healthy adults, a training frequency of at least 3–5 sessions per week is recommended by the ACSM in order to increase and maintaining cardiorespiratory fitness.[29] This strategy allows for adequate recovery between sessions (24–36 hours).[29] From previous studies pertaining to CP, only two studies[24, 25] were aligned with the ACSM guidelines for the frequency of the training. Interestingly, for the remaining studies in which

frequency did not meet minimal recommendations, results demonstrated that training was still effective in increasing the cardiorespiratory fitness.[26–28, 30] This may suggest that for persons with CP who are very deconditioned, it is possible and advisable to start with 1–2 sessions per week and progress gradually thereafter, as adaptations occur.

Intensity

Intensity refers to the effort of training (i.e., relative to maximal capacity), and is frequently prescribed relative to predicted maximal heart rate, heart rate reserve (HRR) (the difference between a person's measured or predicted maximum heart rate and resting heart rate), and/or peak oxygen consumption (peak rate of oxygen consumption as measured during incremental exercise). Two previous studies[25, 27] incorporated the maximum heart rate method to assign training intensity. The study by Verschuren et al.[27] started subjects with a training intensity of 60–70% of maximum heart rate, and increased to 70–80% during the third month. The study by Unnithan et al.[25] used a training intensity of 65–75% of the maximum heart rate, which is also in accordance with the ACSM guidelines (64–95%). Two other studies used a percentage of the HRR. Specifically, in the study by Slaman et al.[28] training started at 40% of HRR and increased the intensity to 80% of the HRR by week 12. Participants in the study by Berg-Emons et al.[26] trained at 70% of the HRR throughout the program, which is also in accordance with the guidelines. The study of Nsenga et al.[24] was also in accordance with the ACSM guidelines, with training intensities ranging between 50–65% of the peak oxygen consumption. Although many factors need to be considered when evaluating these studies and respective findings (e.g., functional capacity of the participants), it is important to point out that intensity of training in each of these 5 RCTs was aligned with current ACSM guidelines. This suggests that many individuals with CP are capable and will benefit in fitness improvement when engaging in progressively-intense aerobic exercise similar to the extent recommended for typically developing peers.

Time

All training sessions lasted for at least 20 minutes, which is aligned with the ACSM guidelines.[29]

Type

For cardiorespiratory fitness, the ACSM recommends regular, purposeful exercise that involves major muscle groups and is continuous and rhythmic in nature.[29] The types of activities provided in the five RCTs included running, step-ups, negotiating stairs, cycling, arm ergometry exercise, propelling a wheelchair, and swimming,[24–28] and all were tailored to the specific condition of the included participants.

Summary of training parameters

Exercise participation can be performed with a high level of safety by most people, including individuals with CP. Based on the safety issues evaluated for the five RCTs, which reported no adverse events, there is a low risk of injury in children and adolescents with CP during cardiorespiratory training. In these studies[24–28] the participants exercised at least 2–4 times per week for a minimum 20 minutes, and at a moderate intensity of about 60–75%

maximum heart rate, 40–80% of heart rate reserve, or 50–65% peak oxygen uptake. Three studies reported outcomes in cardiorespiratory endurance.[24, 25, 28] The other studies reported outcomes in aerobic performance, measured with an arm cranking/cycle test,[26] and shuttle run test.[27] The reported increases were:

- 23% for an 8 week intervention with young people (age: 14.2 ± 1.9 yrs) in GMFCS levels I and II[24]
- 18% for 3 month intervention with those (age: 15.9 ±1.5 yrs) in GMFCS levels II and III[25]
- 9% for 3 month intervention with young adults (age: 20± 3.0 yrs) classified at GMFCS I–IV[28]
- 41% for an 8 month intervention with children (age: 12.1 ±2.6 yrs) in GMFCS levels I and II[27]
- 26% for a 9 month intervention with those (age: 9.2 ±1.4 yrs) in GMFCS levels I–III and possibly even level IV (study predates GMFCS use).[26]

Thus, according to these studies, we can conclude that cardiorespiratory training can effectively increase cardiorespiratory endurance in children and young adults with CP. Taken together, these results suggest that greater gains in cardiorespiratory endurance may occur with training programs of longer duration and for children and adults with CP that have greater mobility and can engage in greater doses of training.

According to the existing intervention studies, exercise prescription for people with CP should include: (1) a minimum frequency of 2–3 times per week; (2) an intensity between 60–95% of peak heart rate, or between 40–80% of the HRR, or between 50–65% of VO_{2peak}; and (3) a minimum time of 20 minutes per session, for at least 8 consecutive weeks, when training three times a week, or for 16 consecutive weeks when training two times a week. Moreover, a pre-workout warm-up and cool-down could be added to reduce musculoskeletal injury.

Adherence Considerations—It might be very difficult for many previously inactive individuals with CP to achieve and sustain these exercise recommendations, and thus it is important to know what is required to maintain adaptations. Moreover, and although we recommend lifelong, regular PA participation, it is also very important to point out that missing exercise sessions or even going through periods of complete attrition is very common. Based on research from individuals who are typically developing, once a regular PA routine is established, short lapses in routine participation will have little or only modest influence on maintenance of cardiorespiratory endurance.[29] Thus, these findings indicate that greater doses of exercise are required to improve cardiorespiratory fitness, than that which is needed to simply maintain adaptations.

Muscle strengthening

The health benefits of enhancing muscular fitness have become well established.[31] Higher levels of muscular strength are associated with significantly better cardiometabolic risk

factor profiles,[32–34] lower risk of all-cause mortality,[35] fewer CVD events,[35] and lower risk of developing functional limitations.[36] As CP results from an injury to motor regions of the developing brain, muscle weakness is a primary impairment and there is strong evidence showing that children with CP are significantly weaker than typically developing children.[7, 8]

In the past, strength training was considered to be contraindicated in people with CP because it was thought to increase muscles stiffness, and result in an increase in spasticity and a decrease in range of motion. However, studies[37–39] have found no change in spasticity during, or after the training, which supports the current belief that strength training for persons with spasticity is not contraindicated. There is even some evidence of improved spasticity with targeted strength training,[40] and therefore, in conjunction with cardiorespiratory fitness, it is imperative to include strategies that target muscle strength in children, adolescents and adults with CP. As with typically developing children, resistance training has the potential to offer observable benefits in terms of increased strength among children, adolescents and adults with CP. A recent systematic review demonstrated that strengthening interventions produce large improvements in strength and physical performance among individuals with CP.[41] However, since there is a paucity of strong evidence from RCTs regarding the use of resistance training in persons with CP,[42] we report the extent to which training protocols from the most recent randomized controlled trials were consistent with the evidence for effective resistance training, as reflected in the training guidelines of the National Strength and Conditioning Association (NSCA)[43] and the ACSM.[29] To maintain the highest level of evidence for these recommendations, we carried out a comprehensive review including only RCTs. We have limited our evaluation to resistance training for the lower extremity, since most of the RCTs in people with CP have incorporated training interventions for these muscles (Table 2).

Frequency

For typically developing children, adolescents and healthy adults, recommendations call for a training frequency of 2–3 times per week on nonconsecutive days.[43] In five RCTs[38, 44–47] that included children, adolescents and adults with CP, the frequency of the training for children with spastic CP was three times a week, and in one RCT[48] the frequency was twice weekly. Therefore, the frequencies of the training were in accordance with the evidence-based NSCA and ACSM guidelines.

Intensity and Volume

According to the NSCA guidelines for youth, novice individuals should use a load that allows no more than 10–15 repetitions for 1–2 sets to be completed, without undue muscle fatigue.[43] Depending on the individual's needs, goals, and abilities, the program can be progressed over time to include greater volumes with heavier loads for large muscle groups, to maximize gains in muscle strength. For the intermediate and advanced individual, the load should be sufficient to allow 6 to 12 repetitions before muscle fatigue, for 2–4 sets.

For adults, gains in muscular hypertrophy and strength result from using a resistance equivalent to 60%–80% of the individual's one-repetition maximum (1RM).[49] Training

intensity may be modified based on a targeted number of repetitions, or by increasing loading within a prescribed repetition-maximum range (e.g. 8- to 12-repetition maximum [RM]).[29] Because it is often challenging or unsafe to ascertain a true 1-RM among individuals with CP, using the latter RM method to assign intensity is the most feasible, safe, and effective strategy. In a recent position stand by the ACSM,[29] progression in training volume and intensity was deemed necessary for strength improvement, even among elderly populations-a recommendation that has since been supported by 2 large meta-analyses.[50, 51]

Volume of training refers to the total number of work sets performed per session (i.e. not including warm-up sets). There has been substantial debate concerning the appropriate operational definition of training volume within the resistance exercise literature, making this a difficult parameter to replicate in research. A widely accepted definition is volume load, which takes into account the total number of performed sets, repetitions and weight (kg) lifted (i.e. (total repetitions [no.] × external load [kg]). Although this is a readily used classification, it is a challenging parameter to prescribe and monitor. Therefore, total number of sets performed per muscle group is a much easier way to track total work performed during training.

According to the NSCA guidelines for novice trainees, the load should be sufficient to allow no more than 6 to 15 repetitions before muscle fatigue, and performed for 1–3 sets.[43] Three trials specified that fatigue was reached within 8–12 repetitions.[38, 44, 48] One trial used two sets of 10 repetitions.[46] Given the low weights that were used in this study, training appeared to be of a very low intensity. Another trial used 4 sets of 4–6 repetitions for the last 6 weeks of an eight week training program.[47] One trial specified that the exercise was performed until fatigue, which resulted in participants completing between 20 and 100 repetitions, and obviously not in accordance with the guidelines.[45] Although many factors need to be considered when evaluating these studies (e.g., exercise technique) it seems, based on the information provided in the six RCTs, that training intensities and volumes were aligned with the NSCA guidelines in only three studies.[38, 44, 48]

Time/duration

The NSCA guidelines state that a short-term youth resistance program should last 8–20 weeks.[43] The duration of resistance training programs included in this overview were between 5 and 8 weeks in four studies.[44–47] In two studies the duration was 12 weeks.[38, 48] The program by Scholtes et al.[38] also lasted for 12 weeks; and yet, the first 6 weeks were [52] used for build-up and practice, leaving 6 weeks of intervention according to the guidelines for intensity and volume.

Most people with CP are not used to strenuous exercise and they may need time to adapt to this level of activity. Therefore, we recommend a few weeks of strength training familiarization simply to reach the recommended training volumes and intensities. Longer interventions with progressive intensities (e.g., 12–16 weeks) may be needed to experience significant or meaningful improvements in strength. Importantly, and as with cardiorespiratory endurance, greater doses of resistance exercise are required to improve muscle strength than is needed to maintain these improvements.[53]

Type of exercises

All four RCTs in children with CP[38, 44–46] used multi-joint exercises (e.g., lateral step-ups, squatting) rather than single joint exercises (e.g., knee extension). The two RCTs that included adults[47, 48] incorporated selectorized weight machines or the seated leg press, and consisted mainly of single joint exercises. Single-joint resistance training may be more effective for very weak individuals or for children, adolescents and adults, particularly at the beginning phases of training, as well as for adults who tend to compensate when performing bilateral, multi-joint exercises. Children, adolescents or adults with CP who are not able to walk independently might also benefit from strength training, but they may lack the selective motor control needed to perform single-joint exercises.

Summary of training parameters

Most of the training parameters in the resistance training RCTs targeted the lower limbs, and were performed according to the NSCA or ACSM guidelines.[43] However, three important parameters that were used in the training programs that were evaluated in the RCTs were not consistent with the NSCA or ACSM guidelines: 1) the mode of exercise; 2) the intensity and 3) the duration of the training program.

As is generally accepted for any novice trainee, prescription of resistance exercise for persons with CP should include a ‘familiarization’ period, in which very low dosage training (i.e. minimal volume and intensity) occurs twice a week for at least 2–4 weeks. We would suggest that simple, single-joint activities be used during this period. However, in children with CP, this is complicated by the varying ability to isolate joint motion, especially at the ankle. After the familiarization phase of training, it may be expected that individuals with CP could safely benefit from gradual increases in dosage to accommodate improvements in strength, endurance, and function. Complex, multi-joint activities (like step-ups and sit-to-stand exercises) could also be added at this time. We recommend performing 1–4 sets of 6–15 repetitions, and gradually progress to meet the demands of improved muscular fitness. It is also important that the programs last sufficiently long to incorporate these two phases of training. Assuming a minimum of 8 weeks to experience changes in strength with simple activities, we would suggest a program of at least 12–16 weeks in order to maximize the likelihood of a training effect in people with CP (Table 2). Because it might be very difficult to adhere to these exercise regimens, it is important to know what is needed to maintain the achieved adaptations Resistance training–induced improvements in muscle strength reverse quickly with complete cessation of exercise.[29] Intensity appears to be an important component of maintaining the effects of resistance training on muscle strength;[54] however, the extent to which different combinations of frequencies, volumes, and intensities can lead to maintenance of adaptation remains unknown.

Physical activity across the activity continuum

Although it is well-established that PA (defined as any bodily movement that results in energy expenditure[55]), cardiorespiratory endurance, and muscle strength are all important for health, evidence also suggests that these are not the only activity-related lifestyles that contribute to health or disease risk. Recent studies have consistently shown that a large

amount of sedentary behaviour, as distinct from a lack of moderate to vigorous PA, is also associated with an increased risk of coronary heart disease, hypertension, diabetes, obesity, mortality and some cancers in the people who are typically developing.[56, 57] Sedentary behaviour (defined as any waking behaviour characterized by an energy expenditure ≤ 1.5 METs while in a sitting or reclining posture[58]) and physical inactivity had previously been seen as two sides of the same coin. They are, however, different constructs on the activity continuum, and have separate contributions to chronic health outcomes.

The PA pattern across the continuum for children, adolescents and adults with CP is therefore important. The increasing number of published studies using objective measurement methods for assessing PA in persons with CP makes it timely to scrutinize the results from these studies. When combining the findings from recent studies that have looked objectively at the PA level of children, adolescents and adults with CP[59–63] we found that children and adults with CP spend 76–99% of their waking hours being sedentary, <18% engaged in light physical activities, and 2–7% in moderate to vigorous activities (only present in GMFCS levels I–III) (see: Figure 1).

Of course, the greatest health risks manifest among persons not meeting PA guidelines, *and* participating in large volumes of sedentary time. The emphasis over the last two decades has been on encouraging moderate to vigorous exercise for children and adolescents with CP. The notion of emphasizing increases in moderate to vigorous PA *and* replacing sedentary behaviour with light PA may be beneficial for health in children and adolescents with CP.

Focusing on the non-exercise segment of the activity continuum involves interventions to promote breaks in sedentary time, and replacement with light-intensity activities. With respect to regular fragmentation of sitting or other sedentary behaviours in a free-living context, this requires an approach that encompasses participation throughout the entire day. Thus, fragmentation of sedentary behaviour is very different from encouraging PA or exercise participation. A recent study[64] showed that by transitioning from seated to a standing position may contribute to the accumulation of light activity and reduce sedentary behaviour among children with CP. Most clinicians do not consider this type of counselling for patients who need to increase PA, as the idea of breaking up sedentary behaviour is not generally thought of as an “intervention”, and yet it merits evaluation due to the viability across the entire CP population.

Baseline Physical Activity

Physical activity guidelines recommend that moderate to vigorous activity be added to baseline levels of activity.[20] Baseline activity includes all light activities (1.5 – 3 METs). However, the concept of baseline PA has been insufficiently defined. We therefore suggest zero activity as a place to begin discussion for people with CP. Since the operational definition of “baseline activity” is at present equivocal, and moreover that evidence supports that light-intensity physical activities are healthier than sedentary activities, there is an obvious need to rethink the true starting point for studying PA behaviours among people with CP.

Too much time spent in sedentary behavior, especially when accrued in long, continuous bouts, is detrimental to cardiometabolic health.[57, 65, 66] Thus, specific interventions aimed at reducing sedentary behavior in people with CP should be considered as a viable, initial target to prevent further cardiovascular complications. Indeed, evidence suggests that frequently interrupting sedentary time may have beneficial effects on metabolic health and hemostasis,[66, 67] suggesting that both the amount and patterns of sedentary behavior contribute to changes in health.

For individuals that participate in high volumes of sedentary behaviour and also engage in little or no PA, the initial dose of activity should include relatively low intensities and of limited duration, with sessions (also called bouts) spread throughout the day and week. Particularly important for individuals who are severely deconditioned, an effective training prescription balances appropriate training stress (at the right training intensity) with adequate recovery. Although exercise intensity must be prescribed above a minimum threshold in order to sufficiently challenge the body to adapt greater cardiorespiratory endurance,[29] it is equally important to provide adequate recovery to ensure optimal adaptations. When this strategy is not adopted, an abnormal training response may occur and a state of overtraining may lead to a diminished return of effectiveness, excessive soreness, fatigue and/or even injury. Health professionals should be aware of these early warning signs of overtraining and modify the physical activities accordingly, as proper conditioning requires a balance between stress/stimulus and recovery. Therefore, successful training programming should incorporate overload; and yet, must avoid the combination of excessive overload plus inadequate recovery. The earlier that overtraining can be detected, the sooner the person with CP will be able to recover. Therefore, frequent evaluations are recommended.

Efforts to promote baseline activities are justifiable and a small but growing body of evidence demonstrates that PA provides health benefits for people with CP. Prior research on the relationship between activity and health has focused on the value of moderate to vigorous activity. Given the emerging benefits of light intensity activities, and the existing confusion of what constitutes baseline activities, it is time to start developing alternative operational definitions and descriptions of PA that are specific to this population. There is insufficient evidence about whether doing more baseline activity results in health benefits; and yet, this may well be the best way to initially fragment SB and lead to sustainable behavior changes in the most sedentary individuals with CP. While this is likely applicable for all children with CP, it is especially relevant for children classified at GMFCS levels IV and V, as reducing sedentary behaviour might be the only viable intervention. Encouraging people with CP to replace sedentary time with baseline activities is sensible for several reasons:

- Increasing baseline activity leads to increased energy expenditure, which, over time, can help with maintaining a healthy body weight.
- Some baseline activities are weight-bearing and may improve muscle and bone health.

- Encouraging baseline activities helps build a lifestyle in which PA is the social norm, and where excessive sedentary lifestyles are discouraged.
- Short episodes of activity are appropriate for people who are previously inactive and have started to gradually increase their level of activity.
- It interrupts prolonged periods of sedentary time which are harmful for health.

Describing the amount of activities needed to maintain and foster health is complicated. The dose-response relationship between volume of moderate and vigorous aerobic activities and all-cause mortality is non-linear, with the most rapid reduction in risk occurring at the smallest increased increment of activity volume, among the most sedentary individuals. Thus, for people who participate in extremely high volumes of sedentary behaviour and are also completely inactive (e.g., most people with CP), even small increases in the volume of activity may lead to profound health gains.

Recent evidence has demonstrated that replacing sedentary behaviour with some light-intensity activity may confer profound health benefits.[68] From a public health perspective, it is more important to understand the dose-response relationships between sedentary, light-intensity, and moderate-intensity activities, and respective health outcomes, than for outcomes associated with vigorous activities. It is quite plausible that light- and moderate intensity activities are important at the lower end of the dose-response curve, in which benefits are gained or lost more quickly. On the other hand, vigorous activities may be more important at the high end of the curve, where changes in relative risk are slower.

In general, people with CP should strive to meet the public health recommendations for daily participation in moderate-to-vigorous PA, and it should be developmentally-appropriate, enjoyable, and involve a variety of activities. Moreover, they should participate in <2hrs/day of non-occupational, leisure-time sedentary activities such as watching television, using a computer, and/or playing video games. However, for a subset of the CP population with excessive frailty, deconditioning, and/or mobility restriction, it is virtually impossible to meet the optimal recommendations of 60 min of moderate to vigorous physical activity. It may also be very challenging for some individuals with CP to engage in less than 2 hours of non-occupational sedentary time. Future research is needed to explore how these guidelines can be applied to individuals with CP, in particular individuals classified at GMFCS levels IV and V.

Discussion and conclusion

Risk for future cardiovascular disease in children and young adults is difficult to define, given that no hard end points, such as disease, cardiac events or death, have yet occurred. Tracking is a method that offers the opportunity to describe the development of a characteristic over time, and involves both the longitudinal stability of the variable and the ability of one measurement to predict the value of a following measurement.[69] The findings from recent tracking studies in the general population provide enough evidence to suggest that the risk factors present early in life are stable over time.[70–73] This has important clinical implications, especially the work[70] showing that a physically active lifestyle starts to

develop very early in childhood and the stability of PA is moderate or high along the life course from youth to adulthood.

Whether the level of physical fitness and muscle strength in children with CP during childhood tracks into, and is predictive of mortality in adulthood, remains to be determined. This would be possible only by performing longitudinal studies, and to date these studies have not been performed among persons in this population. Including health-related outcomes in future registries for people with CP will be vital to provide health care professionals and researchers the first-hand information about certain conditions, both individually and as a group, and over time will increase our understanding of these conditions.

It is imperative that we keep in mind that the sustainability of PA depends on lifestyle behavioral change. For people with CP it might be extremely difficult to achieve the exercise recommendations and physical activity guidelines. Personal and environmental barriers to exercise and physical activity have been previously identified by children and their parents.[74] Not only does the physical disability impose restrictions, but parents or partners may experience time constraints, stress, and financial and psychological burdens which may hinder their ability to commit to such intense recommendations.[75]

Identifying individuals that could benefit from an exercise intervention is important to prevent long term health risks. Cardiopulmonary exercise testing (CPET) is considered the ‘gold standard’ for the assessment of exercise tolerance and cardiorespiratory endurance in people with various medical conditions, as well as in healthy subjects.[76] Exercise testing results can be used to assist clinicians in identifying which patients might be at risk for poor health outcomes, and those who could benefit from an exercise intervention. However, despite the obvious relevance, clinical exercise testing is dramatically underused due to a lack of understanding and training on test administration and interpretation. Clinicians and their staff should encourage patients with CP to be physically active and recommend exercise testing to patients when the child, adolescent or adult experiences limitations in activities due to physical exhaustion. Clinicians must become aware of the importance of exercise among higher-risk populations such as CP, but also regarding the guidelines for how to design patient-tailored exercise programming. The first step in the process is to determine the extent to which patients are physically fit or deconditioned. When fitness is objectively determined through exercise testing, the next step (and possibly the most important one) is to determine whether any deconditioning is due to inactivity, nutritional status, disease-specific pathophysiology, or to a combination of these factors.[77] For children and adults with CP there is a core-set of established, clinically-feasible exercise tests, with an established level of evidence of the clinimetric properties for each outcome measure.[78–80]

Most current evidence concerning the benefits of PA and exercise comes from trials that recruited ambulatory children and adolescents with CP. Implementation of programs based on this evidence is not straightforward, as practical applications of the findings are typically not included. By understanding the barriers and motivators to PA, we may be better able to advise patients to participate. Two recent studies were performed that combined counselling through motivational interviewing and fitness training in children[81] and adolescents[28] with

CP. Both studies included children and adolescents that were classified at GMFCS level I–III (except for one participant who was classified at level IV). Unfortunately both studies were ineffective in stimulating more favourable physical behaviour. The promotion of PA in more disabled children or adults with CP will certainly represent an even greater challenge.

Children with CP are raised in an environment where PA primarily occurs through formal physical therapy sessions and organized sports events for children with disabilities. Their interactions with health professionals are generally related to symptom management, daily function, increased tone and decreased range of motion. These are important concerns, especially during the developmental years, but there is often little discussion of a healthy lifestyles that involve PA and sedentary behaviour reduction. There has been greater awareness of these issues over the past several years, hopefully leading to greater discussion at the patient/health care provider level. Yet, there is much work to be done to promote the encouragement of PA as a part of basic clinic and therapy centre protocols for individuals with CP. Guidelines such as these will greatly contribute to improving knowledge about and comfort with this discussion, and should be used to inform future intervention studies.

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What this paper adds

1. This paper provides an overview of intervention studies including cardiorespiratory endurance training and muscle strengthening for individuals with CP.
2. This paper includes prescription guidelines pertaining to volume, intensity, and duration of physical activity and exercise for individuals with CP.
3. We present the first CP-specific, evidence-based physical activity and exercise recommendations, which may be incorporated into a clinical setting.

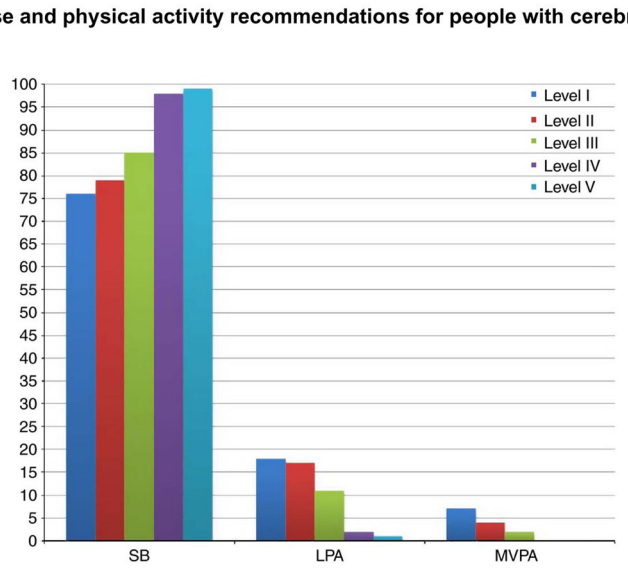

Figure 1. Percentage of time spent in sedentary, light, and moderate to vigorous physical activities across all GMFCS levels

SB=sedentary behavior; LPA= light physical activity; MVPA=moderate to vigorous physical activity.

Table 1

Comparison of Variables of Cardiorespiratory Endurance Training Across Randomized Controlled Trials (RCTs) in Cerebral Palsy (CP) Compared With American College of Sports Medicine (ACSM) guidelines.

	Participants	Frequency	Intensity	Time (session)	Type
Berg-Emons[26]	N=20 Age 7–13 GMFCS I to IV (study predates GMFCS use)	2–4 times a week 9 months	70% HRR	45 minutes	• Cycling • Propelling wheelchair • Running • Swimming • Mat exercises
Unnithan[25]	N=13 Age 14–18 years GMFCS level II/III	3 times a week 12 weeks	65–75% HRmax	20–22 minutes	• Walking • Uphill walking
Verschuren[27]	N=68 Age 7–20 GMFCS level I/II	2 times a week 8 months	60–80% HRmax	45 minutes	Functional exercises: • Running • Steps-up & down • Stepping over • Bending • Turning • Getting up from the floor
Nsenga[24]	N=20 Age 10–16 years GMFCS level I//II	3 times a week 8 weeks	50–65% VO_{2peak}	40 minutes	• Cycling
Slaman[28]	N=42 Age 16–24 GMFCS level I–IV	2 times a week 12 weeks	40–80% HRR	60 minutes	• Treadmill • Cycling • Arm cranking
ACSM[29]		3–5 times a week	64–95% HRmax or 40–89% HRR or 46–90% VO_{2peak}	20–60 or more minutes per session, continuous or intermittentactivity	Regular, purposeful exercise that involves major muscle groups and is continuous and rhythmic in nature

GMFCS= Gross Motor Function Classification System; HRR= Heart Rate Reserve; HRmax = Maximum Heart Rate; VO_{2peak} = Peak oxygen uptake

Table 2

Comparison of Variables of Muscle Strength Training Across Randomized Controlled Trials (RCTs) in Cerebral Palsy (CP) Compared With NSCA and ACSM guidelines.

	Participants	Frequency	Intensity	Time/duration)	Type
Dodd et al.[44]	N=21 Age 8–18 GMFCS I/II/III	3 times a week	3 sets of 8–12 repetitions to fatigue	6 weeks	multi-joint exercises (heel raises, half squats and step-ups)
Liao et al.[45]	N=20 Age 5–12 GMFCS I/II	3 times a week	1 set of 10 repetitions at 20% 1RM 1 set of repetitions until fatigue at 50% 1RM 1 set of 10 repetitions at 20% 1RM	6 weeks	multi-joint exercises (sit-to-stand) loaded (using weight vest)
Lee et al.[46]	N=18 Age 4–12 GMFCS II/III	3 times a week	2 sets of 10 repetitions	5 weeks	multi-joint exercises (squat to stand, lateral step up, stair up and down) loaded (using weight cuffs), single joint exercises
Scholtes et al.[38]	N=51 Age 6–13 years GMFCS level I/II/III	3 times a week	3 sets of 8 RM	12 weeks (6 weeks of PRE)	multi-joint exercises (leg press) and loaded (using a weight vest)
Taylor et al.[48]	N=48 Age 14–22 GMFCS level II/III	2 times a week	3 sets of 10–12 repetitions	12 weeks	Weight machines
Maeland et al.[47]	N=12 Age 27–69 GMFCS II/III	3 times a week	4 sets of 12–15 repetitions (week 1–2) 4 sets of 4–6 repetitions (week 3–8)	8 weeks	Seated leg press (single joint)
NSCA[43]		2–3 times a week	1–3 sets of 6–15 repetitions of 50–85% RM	8–20 weeks	Single and multi-joint exercises

GMFCS= Gross Motor Function Classification System; RM= repetition maximum; PRE= Progressive Resistance Exercise

TABLE 3

Recommendations for exercise and physical activity prescription among people with CP.

	Recommendation
EXERCISE	
Cardiorespiratory (aerobic) Exercise	
• Frequency	• Start with 1–2 sessions a week and gradually progress to 3 sessions a week
• Intensity	• > 60% of peak heart rate, or >40% of the HRR, or between 46–90% VO_{2peak}
• Time	• A minimum time of 20 minutes per session, and for at least 8 or 16 consecutive weeks, depending on frequency (2 or 3 times a week).
• Type	• Regular, purposeful exercise that involves major muscle groups and is continuous and rhythmic in nature
Resistance Exercise	
• Frequency	• 2–4 times a week on nonconsecutive days
• Intensity	• 1–3 sets of 6–15 repetitions of 50–85% RM
• Time	• No specific duration of training has been identified for effectiveness. Training period should last at least 12–16 consecutive weeks
• Type	• Progression in mode from primarily single-joint, machine-based resistance exercises to machine plus free-weight, multi-joint (and closed-kinetic chain) resistance exercises. Single-joint resistance training may be more effective for very weak muscles or for children, adolescents or adults who tend to compensate when performing multi-joint exercises, or at the beginning of the training
DAILY PHYSICAL ACTIVITY	
Physical activity (moderate to vigorous)	
• Frequency	• ≥5days/week
• Intensity	• Moderate-to-vigorous physical activity
• Time	• 60 min
• Type	• A variety of activities
Physical activity (sedentary)	
• Frequency	• 7days/week
• Intensity	• Sedentary (<1.5 METs)
• Time	• <2hrs/day or break up sitting for 2 minutes every 30–60 minutes
• Type	• Non-occupational, leisure-time sedentary activities such as watching television, using a computer, and/or playing video games