

Relation between physical fitness and gross motor capacity in children and adolescents with cerebral palsy

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AIM To examine the relation between physical fitness and gross motor capacity in children with cerebral palsy (CP) who were classified in Gross Motor Function Classification System levels I or II.

METHOD In total, 68 children with CP (mean age 12y 1mo, SD 2y 8mo; 44 males, 24 females; 45 classified as having spastic unilateral CP, 23 as having spastic bilateral CP) participated in this study. All participants performed a maximal aerobic exercise test (10m Shuttle Run Test), a short-term muscle power test (Muscle Power Sprint Test), an agility test (10×5m sprint test), and a functional muscle strength test (30s repetition maximum) within 2 weeks. Gross motor capacity was concurrently assessed using dimensions D (standing) and E (walking, running, and jumping) of the 88-item version of the Gross Motor Function Measure (GMFM).

RESULTS No relation between aerobic capacity, body mass index, and dimensions D and E of the GMFM was found. The correlations between short-term muscle power, agility, functional muscle strength, and dimensions D and E of the GMFM were moderate to high ($r\sim 0.6\text{--}0.7$).

INTERPRETATION The relations found between short-term muscle power, agility, functional muscle strength, and gross motor capacity indicate the importance of these components of physical fitness, and may direct specific interventions to maximize gross motor capacity in children and adolescents with CP.

Children with spastic cerebral palsy (CP) often have poor physical fitness (aerobic capacity, muscle strength, anaerobic muscle power, and agility), which may also compromise their daily physical functioning. Affected fitness components include muscle strength, aerobic capacity, and short-term muscle power.^{1–4}

During the past decade there has been increasing interest in physical exercise for children with CP. Most of the current programme-related literature about children with CP has focused on aerobic capacity and muscle strength.⁵

Less attention has been paid to agility and short-term muscle power. This is surprising, considering that almost all daily childhood activities involve bursts of short-term, high intensity muscle power, rather than long-term patterns.⁶

A link between low physical fitness and low gross motor capacity in paediatric patients with chronic disease was suggested by Bar-Or.⁷ However, there are no data on whether aerobic capacity, short-term muscle power, agility, and muscle strength (as measured during a standardized test) can be related to gross motor capacity in children and

adolescents with CP. A recent study performed by Aires et al.⁸ suggests that overweight children have lower physical fitness levels than peers of normal weight. Therefore, body composition might influence the gross motor capacity of children and adolescents as well.

Improving the ability to stand, walk, run, and jump, or to perform important functional activities, is often the primary goal of therapy for children with CP.⁹ Gait abnormalities in children with CP have been shown to increase submaximal walking energy expenditure compared with that in healthy children. The working mechanisms giving rise to the high energy cost of locomotion in children with CP might be due to co-contraction, among other factors.¹⁰ Maltais et al. suggested that the energy cost of walking in children and adolescents with mild CP was strongly related to daily activity.¹¹ Children with CP who lack the requisite fitness capacity may not be able to achieve their maximum potential in gross motor activities. Consequently, they may be unable to perform various activities of daily living that are important for independence.

The aim of this study was to determine how, and to what extent, fitness components are related to static (standing) and dynamic (walking, running, and jumping) gross motor activities in children and adolescents with CP who were classified in GMFCS levels I or II.

METHOD

Sixty-eight children and adolescents with CP (44 males, 24 females; mean age 12y 1mo, SD 2y 7mo, range 7–18y) from four schools for special education in the Netherlands participated in this study. This was part of a larger study that evaluated the effects of an exercise programme for children and adolescents with CP.¹² For the present study, the baseline measurements of the intervention study, for which all participants and parents/carers gave written informed consent, were used. The institutional ethics committee of the University Medical Center, Utrecht approved the study. To be included, participants had to be in the age range 7 to 20 years, diagnosed with spastic CP, and classified at levels I or II in the Gross Motor Function Classification System (GMFCS). Children over 12 years of age were classified using the same criteria as those used for 6- to 12-year-olds. All children in the study were able to follow simple verbal commands. Participants were excluded if they had orthopaedic or neurosurgery and/or botulinum toxin injection(s) within 6 months before study entry, or cardiac or respiratory conditions that could be negatively affected by exercise. Table I shows the GMFCS level and distribution of motor impairment of the participants.

Table I: Characteristics of participants (*n*=68)

Mean age, y:mo (SD)	12:1 (2.8)
Males:females	44:24
Cerebral palsy: classification and distribution, <i>n</i>	
GMFCS level I	47
GMFCS level II	21
Spastic unilateral	45
Spastic bilateral	23

GMFCS, Gross Motor Function Classification System.

Measurements

Aerobic capacity

Aerobic capacity was reflected by the achieved level on the 10m Shuttle Run Test.¹³ This test requires children to walk or run between two markers delineating the 10m course, at a set incremental speed determined by a signal (every minute). The starting speed for the 10m Shuttle Run Test is 5km/h and 2km/h for children who are classified in GMFCS levels I and II respectively, with the speed increased 0.25km/h every minute. The achieved level was recorded and used for analysis. This test has been shown to be reliable and valid in children with CP.¹³

Body composition

Body composition was reflected by the body mass index (BMI). The BMI was calculated as the weight in kilograms divided by the square of the height in metres. Participants' weights and heights were measured using a standard protocol. Each child was weighed to the nearest 100g on electronic scales (Seca, Hamburg, Germany). Height was measured to the nearest 0.5cm using a stadiometer.

Short-term muscle power

Short-term muscle power was measured using the mean power (in watts) derived from the Muscle Power Sprint Test.¹⁴ This test has been shown to be reliable in children with CP.¹⁴ For the test, the children were instructed to complete six 15m runs at maximum pace. Between each run, the child was allowed a timed 10 second rest. Mean power output (in watts) was calculated based on the child's body weight and the average time taken to perform the six all-out sprints.¹⁴

Agility

Agility is the ability to change the direction of the body in an efficient and effective manner. To achieve this, a child needs a combination of balance, speed, and coordination. Agility was assessed using the 10×5m sprint test.¹⁴ This is a continuous sprint test in which the child has to make nine fast turns after finishing every 5m. At the end of the 10th

turn the child has to cross the finish line. This test has been shown to be reliable and valid in children with CP.¹⁴ The time taken to perform this test was recorded and used for the analysis.

Functional muscle strength

Functional muscle strength of the lower extremity was measured with the 30s Repetition Maximum test.¹⁵ In this test, the following three closed kinetic chain exercises were chosen: (1) lateral step-up test, (2) sit to stand, and (3) attain stand through half kneel. The children were instructed to perform as many repetitions as possible in 30 seconds for each of the exercises. Exercises 1 and 3 were assessed bilaterally. Total scores for the left and right side were calculated from the repetition maximum for each side, so in total five scores were calculated. The number of repetitions were recorded and used in the analysis. This test has been shown to be reliable in children with CP.¹⁵

Gross motor capacity

Gross motor capacity was assessed using dimensions D and E of the Gross Motor Function Measure (GMFM), which measures respectively activities in standing, and walking, running, and jumping.¹⁶ This test has been shown to be reliable in children with CP. These dimensions were chosen because they are difficult for many young people with CP who are ambulatory.¹⁷

Procedure

All the participants performed the tests within 2 weeks. In total eight assessors, who were not the treating therapists, undertook the testing. Before data collection, all assessors had formal training and were given written instructions on the application and scoring of the tests and measurements. The eight assessors were randomly assigned to one of the four schools for special education, resulting in two

assessors per site. To monitor the reliability of the GMFM, all the assessors were tested using a criterion test videotape.

Statistical analysis

The means and standard deviations for all data were calculated. The distribution of the data was checked for normality by the Kolmogorov–Smirnov test. This test showed that for all measurements the distribution was not significantly different from a normal distribution. A Pearson's partial correlation test (controlled for age, sex, and GMFCS level) was performed to assess the relation between aerobic capacity, BMI, and dimensions D and E of the GMFM. To evaluate the effect of agility, short-term muscle power, functional muscle strength and gross motor capacity partial correlation coefficients (controlled for age, sex, and GMFCS level) were calculated. The partial correlation (*r*) assesses the 'true' strength of a relation between two variables by taking into account the effect that age, sex, and GMFCS level have on that relation. The correlation is graded as: 0 to 0.25 little; 0.26 to 0.49 low; 0.50 to 0.69 moderate; 0.70 to 0.89 high; and 0.90 to 1 very high.¹⁸

We analysed all statistics with the Statistical Package for the Social Sciences, version 13.0 (SPSS, Chicago, IL, USA). Statistical significance was set at a *p*<0.05.

RESULTS

Descriptive statistics for aerobic capacity, BMI, short-term muscle power, agility, and functional muscle strength are shown in Table II. The wide range of participants' characteristics shows the variation in physique of children and adolescents with CP.

Partial correlations between parameters of aerobic capacity, anaerobic capacity, agility, functional muscle strength, and GMFM scores are shown in Table III. As

Table II: Statistics of fitness measures and gross motor capacity

Fitness components	Mean	SD	Range
Aerobic capacity, level on the 10m Shuttle Run Test, min	6.9	4.1	1.0–20.0
Body mass index, kg/m ²	19.7	4.1	12.5–30.9
Short-term muscle power (W)	102.9	84.9	6.0–320.3
Agility (10×5m sprint test), s	32.1	8.8	18.6–59.9
Functional muscle strength left, 30s Repetition Maximum (total number of repetitions)	35.7	18.7	7.0–79.0
Functional muscle strength right, 30s Repetition Maximum (total number of repetitions)	35.3	19.2	7.0–89.0
Gross motor capacity			
GMFM dimension D (standing)	90.7	9.2	43.6–100
GMFM dimension E (walking, running, jumping)	88.1	12.0	55.6–100

GMFM, Gross Motor Function Measure.

Table III: Partial correlation coefficients between gross motor capacity and fitness measures

Fitness components	GMFM dimension D (standing)	GMFM dimension E (walking, running, jumping)
Aerobic capacity (10m Shuttle Run Test)	-0.1	0.0
Body mass index (kg/m ²)	-0.2	-0.1
Short-term muscle power (Muscle Power Sprint Test)	0.3 ^a	0.6 ^a
Agility (10×5m sprint test)	0.6 ^a	0.7 ^a
Functional muscle strength left, 30s Repetition Maximum test	0.5 ^a	0.7 ^a
Functional muscle strength right, 30s Repetition Maximum	0.5 ^a	0.7 ^a

can be seen in Table III, there was no significant correlation between aerobic capacity and BMI and gross motor capacity. Table III shows a moderate to high correlation between short-term muscle power, agility, functional muscle strength, and gross motor capacity as measured with dimensions D and E of the GMFM.

Figure 1 shows the relation between aerobic capacity and BMI and gross motor capacity (GMFM dimension E). Figure 2 shows the relation between short-term muscle power, agility, and functional muscle strength and gross motor capacity (GMFM dimension E). Both figures illustrate a large variation in fitness parameters between children with the same GMFM scores on dimension E.

DISCUSSION

The aim of this study was to determine whether there is a relation between aerobic capacity, short-term muscle power, agility, functional muscle strength, and gross motor capacity in children with CP. Although factors related to gross motor capacity and disability can be explored using tests of physical fitness, it is not common practice to perform these tests in children with CP. In this study we used field tests, which are easy to perform, to explore the physical fitness of children with CP.

Physical fitness may be subdivided into health-related fitness and performance-related fitness.¹⁹ Cardiorespiratory fitness and body composition are considered the two major components of health-related fitness because of their apparent relation to health in adults.²⁰ Balance, coordination, speed, agility, and short-term muscle power are often

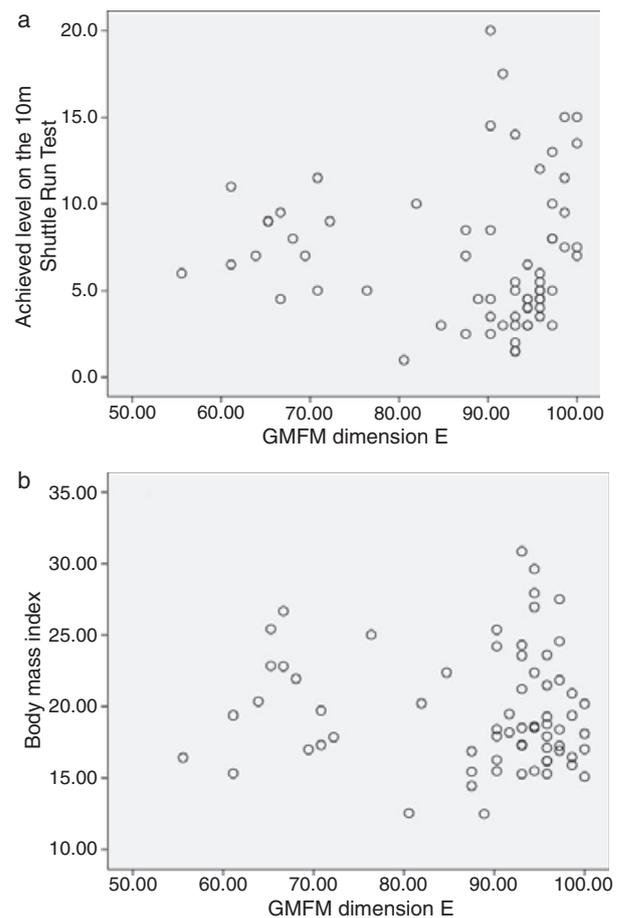


Figure 1: A scatterplot showing the relationship between (a) aerobic capacity and (b) BMI and gross motor capacity (Gross Motor Function Measure, dimension E).

described as performance-related fitness. The findings in this study support the idea that these components respectively assessed using the 30s Repetition Maximum test, the 10×5m sprint test, and the Muscle Power Sprint Test, are related to performance for children with CP who are classified in GMFCS levels I or II. Further research should assess if cardiorespiratory fitness and body composition are related to health in children and adolescents with CP.

In the child with neuromuscular disease it is muscle function rather than aerobic fitness that is usually affected, which subsequently limits the child's physical capacity.²¹ Exercise training interventions for children and adolescents with CP are often developed to improve their gross motor capacity. When developing an exercise programme for children with CP, it is important to realize that the performance-related fitness components are related to gross motor capacity (static and dynamic). Based on this study, we recommend considering functional muscle strength,

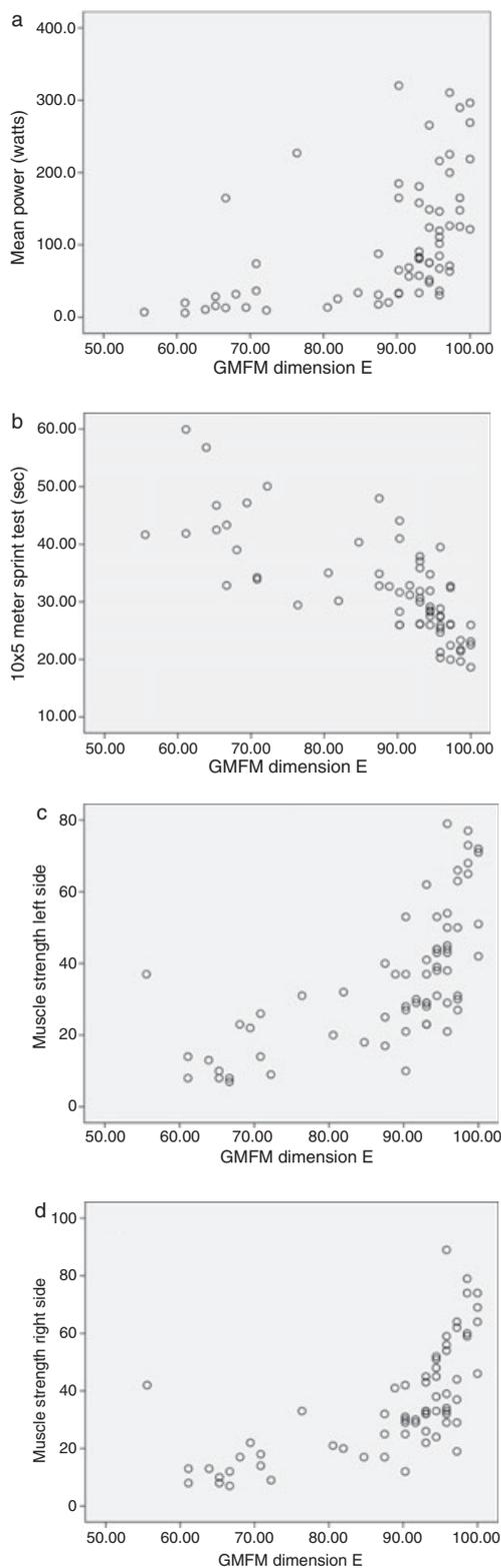


Figure 2: A scatterplot showing the relationship between (a) short-term muscle power, (b) agility, (c) functional muscle strength left side and (d) right side, and gross motor capacity (Gross Motor Function Measure, dimension E).

agility, short-term muscle power, and balance in the training repertoire of children and adolescents with CP. However, the efficacy of such a training programme remains to be determined and can be settled only in an intervention study of sufficient size.

The moderate to high correlation between performance-related fitness components and walking, running, and jumping (GMFM dimension E) is probably because the skills assessed in this dimension are more related to skills that involve lower-extremity performance than standing (GMFM dimension D). Moreover, because many daily childhood activities consist of short bursts of high intensity activity, short-term muscle power is thought to be an important indicator of gross motor capacity. Observations of children suggest that their activity patterns are characterized by short, intense bursts.⁶ Impaired short-term muscle power means that certain activities cannot be performed at the same pace as healthy children, or cannot be performed at all. This type of activity pattern in children might explain the effectiveness of measuring short-term muscle power over aerobic capacity. This result supports the ideas of Bar-Or who stated that, for children with a neurodevelopmental disease, short-term muscle power is a better measure of gross motor capacity than aerobic capacity.⁷

In this study, functional muscle strength, measured with the 30s Repetition Maximum test, was related to gross motor activity. These findings agree with studies performed by Damiano et al.²² and Ross and Engsborg²³ Both studies found a high correlation between muscle strength, measured with a hand-held myometer, and GMFM. The 30s Repetition Maximum test measures muscle strength in a functional way and requires balance, coordination, and anaerobic performance. Therefore, this measure is more performance related than the hand-held myometer.

The findings of this study do not mean that we should not focus interventions on increasing aerobic capacity, because aerobic fitness is a strong indicator of mortality in adulthood.²⁴ A recently published paper described an exercise programme for children with CP. The main focus of the final 4 months of this programme was on anaerobic capacity (short-term muscle power).¹² The significant interaction in favour of the training group during the final 4 months of training showed that a fitness training programme with a predominantly anaerobic nature was able to improve the anaerobic capacity in children with CP. Moreover, in the final 4 months the children in the training group improved their aerobic capacity and functional muscle strength as well. This shows that when training the anaerobic capacity, the aerobic capacity improves as well. This is in accordance with studies of healthy children,

which have shown an increase in aerobic capacity after anaerobic training.^{25,26}

Adherence to exercise programmes depends on individual motivation and variation in activities. Children and adolescents are more likely to enjoy a short-term, high-intensity training programme because it can offer the necessary variation. Given the moderate to high correlations between performance-related fitness and gross motor capacity found in this study, it would be interesting to study the effects of a purely performance-related exercise programme on children with CP who are classified in GMFCS levels I and II.

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CONCLUSION

This study described the relation between physical fitness and gross motor capacity in children and adolescents with CP. There were moderate to high correlations between performance-related fitness components and gross motor activities for these individuals. These results may help in the formulation of exercise training interventions in order to maximize gross motor capacity in children and adolescents with CP. This, in turn, will help to enhance and maintain their motor abilities in daily life.