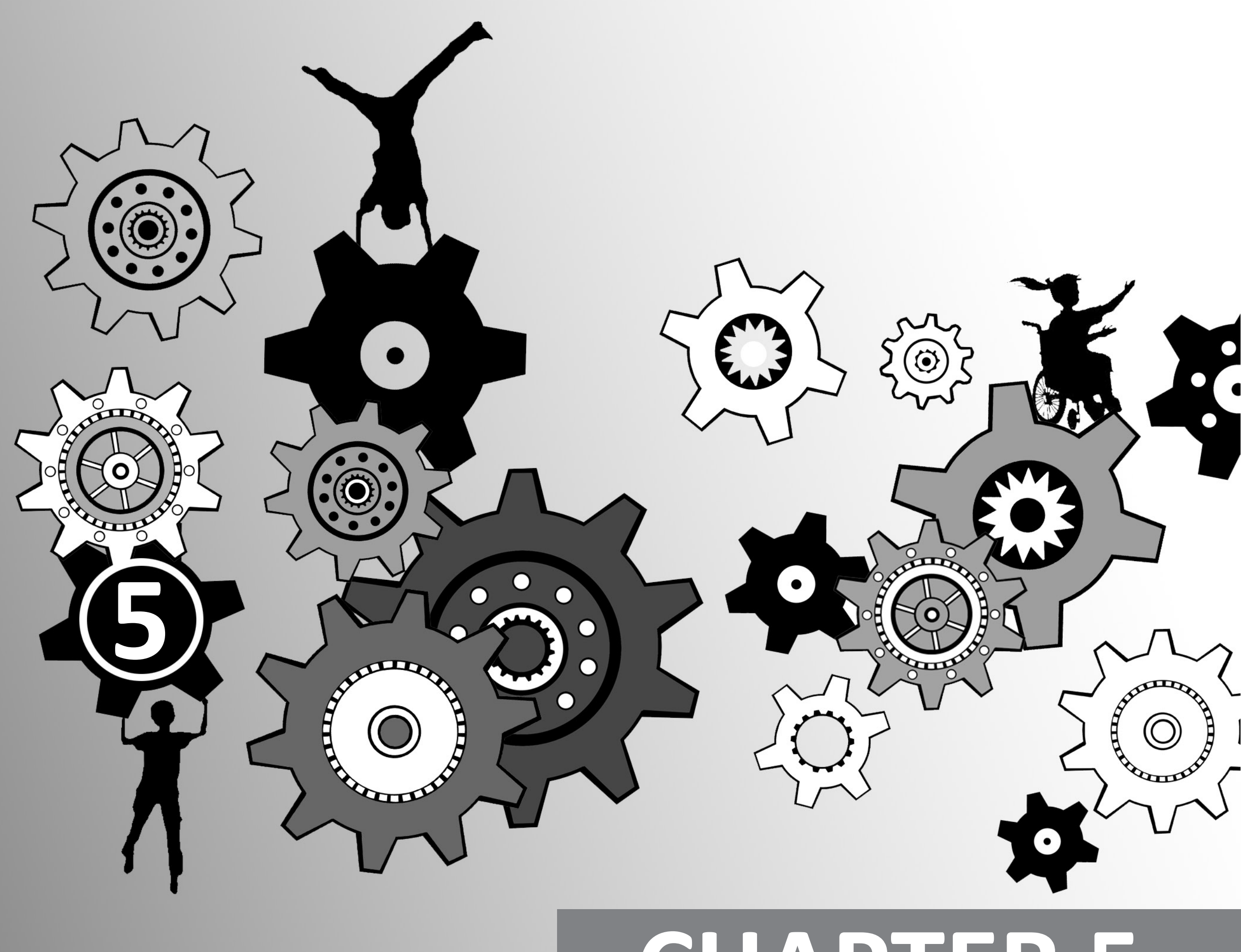

CHAPTER 5

Fitness and Mobility Capacity in School-aged Children with Cerebral Palsy: a Longitudinal Analysis

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Submitted

ABSTRACT

Introduction: The purpose of this study was to determine the longitudinal relationship among fitness components and between fitness and mobility capacity in children with cerebral palsy (CP).

Methods: Forty-six children with a bilateral (N = 24) or a unilateral spastic CP (N = 22), aged 7-13 years, participated in aerobic and anaerobic fitness measurements on a cycle ergometer and isometric muscle strength tests. Mobility capacity was assessed with the gross motor function measure (GMFM) and a walking capacity test. Longitudinal relationships (3 or 4 measurements over one year) were determined using repeated measurements analyses.

Results: In children with bilateral CP, aerobic fitness was strongly related to anaerobic fitness ($p < 0.001$), while aerobic fitness showed a weak relationship with muscle strength ($p < 0.05$). Anaerobic fitness was not related to muscle strength. No relationships between fitness components were found in unilateral CP. Anaerobic fitness and muscle strength were significant determinants for GMFM and walking capacity in bilateral but not in unilateral CP.

Conclusion: The strong longitudinal relationship between aerobic and anaerobic fitness indicates that increasing either aerobic or anaerobic fitness corroborates with improvements in the other fitness component in children with bilateral CP only. While increasing anaerobic fitness might be beneficial for mobility capacity in children with bilateral CP, this is less likely for children with unilateral CP.

INTRODUCTION

Emerging evidence shows that fitness is an important health indicator in all individuals.[5;14] Adequate fitness might be even more important for persons with a physical disability, who often have lower levels of fitness and higher risks of developing secondary health conditions including obesity, diabetes and cardiovascular disease.[18] It has also been suggested that adequate fitness in children with a physical disability associates with a better capacity to execute daily activities.[3] The most common physical disability in childhood is cerebral palsy (CP), a group of motor disorders characterized by activity limitations due to motor impairments.[17;26] As decreased fitness levels might increase the impact of CP on activities of daily living,[7] improving fitness might therefore be an important issue to consider when aiming to lower the impact of the disorder on activities of daily living, and to improve general health in persons with CP.

There is accumulating evidence that children with CP have decreased aerobic fitness, anaerobic fitness and muscle strength.[2;36;39] Decreases in muscle strength and anaerobic fitness might be expected in light of the impaired muscle activation in CP, whereas aerobic fitness seems to be more closely related to physical inactivity.[2] While muscle strength training has received increasing attention over the years,[40] interventions aimed at improving aerobic fitness have been undertaken less often.[25] Studies addressing aerobic fitness training focused on adolescents [4] or used field tests to estimate aerobic fitness, which also depend on walking ability such as time to complete a running test.[42] Objective assessments that measure aerobic fitness directly, such as peak oxygen uptake, the anaerobic threshold, oxygen pulse and ventilatory factors have been evaluated less frequently following interventions in children with CP.[23;35] More recently, it was suggested that more high intensity short duration (anaerobic) components should be included in fitness training programmes.[20] This type of training better suits the activity patterns of children and is promising in regard to improving aerobic and anaerobic fitness.[1;20] However, a recent multi-component intervention including both fitness training including strength and anaerobic exercises, combined with a lifestyle intervention, showed no effect on physical fitness.[13] In both groups a large inter-individual variation in changes in physical fitness was found, indicating that some subjects improved, while others deteriorated despite their group allocation. A secondary analysis on these data allows investigation of relationships between changes in physical fitness which might have been averaged out in the group mean values, and also allows subgroup differentiation in these relationships.[19]

Apparently, a better understanding of limited maximal exercise is required to provide guidance in setting up training programmes aimed at improving fitness in children with CP. A recent cross-sectional study suggested that aerobic and anaerobic fitness are limited by reduced muscle strength.[11] This was indicated by the stronger correlations between these fitness components in adults with CP than in controls.[11] Due to the differences in coordination and muscle function between unilateral and bilateral involved CP, a different relation among fitness components might also be expected. The strong cross-sectional correlations in the previously mentioned study may be influenced by the large inter-individual variability of fitness levels in subjects with CP. This cross-sectional relationship does not preclude a relation between changes in fitness components. Therefore, longitudinal relationships might provide better insights into whether a change in one fitness component is related to a change in the other.[34]

Associations of muscle strength and anaerobic fitness with mobility capacity were shown in cross-sectional studies.[24;41] However, strength training studies showed that improvements in muscle strength did not necessarily lead to increased mobility capacity.[29;30;32] Moreover, evidence for a better mobility capacity as a result of improved anaerobic and aerobic fitness is even sparser.[42] The above-mentioned differing relationships in unilateral and bilateral CP may also apply to relations between fitness and mobility capacity. Since mobility capacity is highly related to the severity of the motor disorder, the anatomical involvement is likely to influence this relation.[15] Therefore, stronger relationships among fitness components and between fitness and mobility capacity are expected for children with a bilateral CP than for children with a unilateral CP, since children with a bilateral CP are more limited by muscle strength and coordination. The purpose of this study was to investigate the longitudinal relations between changes in the fitness components aerobic fitness, anaerobic fitness and muscle strength, and between fitness and mobility capacity in children with CP.

METHODS

Participants

This study is a secondary analysis of a 6-month single-blinded, randomized controlled trial, with a 6-month follow-up, to assess the effects of a physical activity stimulation program *(LEARN 2 MOVE 7-12* study*).*[38] Children with spastic CP were recruited in special schools for children with disabilities and pediatric physiotherapy practices in the Netherlands, between September 2009 and February 2012. The intervention program included 49 children with CP. A total of 46 children completed the study. Children were included when the following criteria were met: 1) 7-13 years old; 2) Gross Motor Function Classification System (GMFCS) level I, II or III; 3) no history of botulinum toxin injections and/or serial casting in the past 3 months or surgery in the past 6 months; 4) no contraindications for maximal exercise; and 5) less active than the international physical activity norm, no regular participation in sports or (physiotherapeutic) fitness program, and experience of problems related to daily life mobility or sports.[37] The institutional ethics committee of the VU University Medical Center approved this study and all participants above 12 years of age and all parents signed an informed consent.

Study design

This study included measurements at baseline, 4 months, 6 months and 12 months, which were performed at approximately the same time during the day within each child.

A measurement session took place at the outpatient unit of a university medical centre and included determination of anthropometry, physical fitness and mobility capacity. The children were instructed not to eat or drink (except for water) 1.5 hours prior to the measurement session. All measurements, except for the walking test, were performed in a laboratory with a temperature between 19-22 °C and a relative humidity of 41-50%. Fitness testing consisted of a maximal aerobic exercise test, an anaerobic Wingate test, isometric strength testing of the knee extensors and the hip abductors, after which mobility capacity was determined by measuring gross motor function and walking capacity.

Outcome measures and materials

Anthropometry

Measures of body height [m] and weight [kg] were determined using an electronic scale (DGI 250D, KERN DE version 3.3 10/2004; Kern & Sohn GmbH Balingen-Frommern). Body mass index (BMI [kg/m^2]) was calculated. Skinfold was measured at the supra-iliac and the sub scapular site using a Holtain skinfold caliper (ProCare BV, Groningen, the Netherlands) with an accuracy of 0.2 mm, providing a summed score of skinfold thickness [mm].[31]

Physical fitness

Physical fitness was comprised of aerobic fitness, anaerobic fitness and isometric muscle strength. Aerobic fitness was determined during a maximal aerobic exercise test performed on a cycle ergometer (Corival V2; Lode B.V., Groningen, the Netherlands). The protocol was based on the McMaster protocol and consisted of a resting period enabling habituation to the mask used for gas analysis, 3 min of warming-up, 5 min of submaximal cycling and a maximal phase with the load increased each minute. The load increments were adapted to match the abilities of the child.[2] Respiratory gas was collected breath-by-breath with a gas analysis system. The corresponding software (Quark CPET, Cosmed, S.r.l., Rome, Italy) was calibrated with a known mixture prior to testing. Heart rate was measured with a heart rate monitor (Cosmed, S.r.l., Rome, Italy). Maximal aerobic parameters were calculated over the 30 s with the highest sustained load. Achievement of maximal aerobic exercise was checked using objective criteria: heart rate (HR) > 180 or respiratory exchange ratio (RER) > 1.00, and if subjective exhaustion was present.[2] Maximal aerobic parameters were VO_2peak, peak O_2pulse (VO_2/HR [$mL \cdot beat^{-1}$]), peak ventilation (VEpeak [$L \cdot min^{-1}$]). The anaerobic threshold (AT) was determined with the V-slope method by 2 independent raters. The test-retest reliability of this protocol for VO_2peak was shown to be excellent in children with CP, with an intraclass correlation coefficient (ICC) of 0.94 and a standard error of measurement (SEM) of 2.06 $ml \cdot kg^{-1} \cdot min^{-1}$.[6] Anaerobic fitness was measured using the 20 s Wingate anaerobic cycling test, which is a sprint test against a constant breaking torque. The test was performed for 20 s, providing the delivered mean power over 20 s (P20mean [$W \cdot kg^{-1}$]), which was used for analyses. Reliability assessment of P20mean using this protocol showed high ICCs of 0.96-0.99 and SEMs of 0.148-0.270 $W \cdot kg^{-1}$.[8] Isometric muscle strength of the knee extensors and hip abductors of the most-affected leg was determined via hand-held dynamometry.

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The ‘make test’ was performed with the child pushing against the dynamometer (MicroFet; Biometrics, Almere, the Netherlands) for 3 s with maximal force, while the leg was fixed by the assessor according to standardized procedure.[44] Strength (N) was multiplied by the moment arm resulting in the torque [Nm], and the mean of 3 measurements was calculated. Intersession reliability was found to be good with ICC > 0.82 and SEMs of 0.55 $N \cdot kg^{-1}$, (knee extensors) 1.21 $N \cdot kg^{-1}$ (hip abductors).[44] Measurements were performed by the same assessor in each measurement session.

Mobility capacity
Gross motor function was determined with the Gross Motor Function Measure item sets (GMFM-IS).[28] The Gross Motor Ability Estimator (GMAE) was used to calculate the GMAE score.

Walking ability was assessed using the 1 min walk test. Children were asked to walk as fast as possible, without running, on an oval walkway for 1 min. Covered distance [m] was registered. This test was reliable in children with CP with an ICC of 0.94 and limits of agreement of 13.1 m.[21]

Statistics

Longitudinal relationships among fitness components and between fitness components and mobility capacity were determined with a univariate random coefficient analysis. This analysis corrects for the dependency of observations within one individual by estimating a random intercept and slope (if this shows a better fitting model).[34] Effect modification was investigated to determine whether the relationships were different for children with unilateral involvement and bilateral involvement. To assess determinants of mobility capacity a multiple random coefficient regression model was applied, using a forward selection procedure. Fitness variables that were significantly associated with mobility capacity ($p < 0.05$) in the univariate analysis were included as determinants in the multiple regression model. Variables with strongest association were added to the model first and included if level of significance was $p < 0.05$. Data on walking capacity was corrected for height if the regression coefficient changed > 10%. Analyses were carried out using IBM SPSS Statistics, version 20 (SPSS Inc, Chicago, Illinois, USA).

RESULTS

Participants

Characteristics of the participants are listed in Table 5.1. All children agreed to participate in all measurements, except for two children who were unable to perform measurements at 12 months for practical reasons. At all measurement sessions, there were missing data for a variety of reasons including refusal to wear the mask, lack of motivation or equipment problems.

TABLE 5.1 Patient Characteristics

	All children (N=46)	Bilateral CP (N=24)	Unilateral CP (N=22)
Boy/Girl	26/20	12/12	14/8
Age [year]	9y7mo (1y8mo)	9y6mo (1y4mo)	9y8mo (2y)
Heigth [cm]	136.8 (12.4)	133.3 (8.6)	140.7 (14.7)
Weight [kg]	34.8 (11.1)	31.7 (7.9)	38.2 (13.1)
BMI [kg·m^{-2}]	18.2 (3.3)	17.7 (3.3)	18.7 (3.1)
Skinfold [mm]	26.3 (10.3)	26.0 (10.9)	26.7 (9.7)
GMFCS (I/II/III)	26/12/8	8/8/8	18/4/0

Abbreviations: CP: Cerebral palsy; GMFCS: Gross Motor Function Classification System.

Longitudinal relations

Table 5.2 shows the descriptives of fitness and mobility capacity. Significant interactions showed that relations among fitness components and of fitness components with mobility capacity were different for children with unilateral involvement than for those with a bilateral involvement. Therefore, descriptives and relations were presented for the whole group, and separately by anatomical involvement (Table 5.3, 5.4 and 5.5).

Relations between fitness components

Table 5.3 and 5.4 show the relations among the fitness components aerobic fitness, anaerobic fitness and muscle strength. In children with bilateral CP, aerobic fitness parameters (VO_2peak (p < 0.001), AT and O_2pulse (p < 0.05) were related to anaerobic fitness, while aerobic fitness (VE/VO_2 only) showed a weak relationship with muscle strength (knee extensors and hip abductors) (p < 0.05). Anaerobic fitness was not related to muscle strength. In children with unilateral CP, no relations among fitness components were found.

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Relations with mobility capacity

Univariate analyses showed that in children with a bilateral CP, VO_2peak (p < 0.05), anaerobic fitness (p < 0.001) and knee extensor strength (p < 0.05) were related to gross motor function, while VO_2peak (p < 0.05), anaerobic fitness (p < 0.001) and hip abduction strength (p < 0.001) were related to walking capacity (Table 5.5). Fitness components and mobility capacity were not related in children with a unilateral CP (Table 5.5). The multivariate models showed that anaerobic fitness and muscle strength were the most important determinants of gross motor function and walking capacity in children with a bilateral CP (Table 5.6), whereas in children with a unilateral CP, no fitness components were determinants for mobility capacity.

DISCUSSION

This was the first study to investigate the longitudinal relationships among the fitness components aerobic fitness, anaerobic fitness and muscle strength, and between fitness and mobility capacity in children with CP. The results showed that in children with bilateral CP, changes in aerobic fitness were strongly related to changes in anaerobic fitness, while

TABLE 5.2 Descriptives of Mobility Capacity and Fitness

	Descriptives (Mean (SE))							
	Baseline	*N*	4 months	*N*	6 months	*N*	12 months	*N*
Mobility capacity								
GMAE score								
Overall	78.8 (2.0)	*46*	na		79.2 (2.0)	*46*	80.0 (2.1)	*44*
Bilateral	72.5 (3.2)	*24*	na		73.6 (3.1)	*24*	73.8 (3.3)	*23*
Unilateral	85.6 (1.5)	*22*	na		85.2 (1.6)	*22*	86.7 (1.5)	*21*
Walking capacity [m]								
Overall	89.0 (3.0)	*46*	92.7 (3.2)	*44*	93.9 (3.2)	*45*	91.8 (3.4)	*42*
Bilateral	77.5 (3.9)	*24*	81.2 (3.8)	*25*	81.6 (4.1)	*23*	79.8 (4.2)	*23*
Unilateral	101.6 (2.6)	*22*	107.8 (2.9)	*19*	106.8 (3.0)	*22*	106.2 (3.2)	*19*
Fitness								
Aerobic fitness								
VO_2peak [ml·kg^{-1}·min^{-1}]								
Overall	31.4 (1.0)	*38*	34.0 (1.2)	*34*	33.9 (1.1)	*35*	33.5 (1.2)	*35*
Bilateral	29.0 (1.5)	*18*	34.1 (2.1)	*17*	31.4 (1.8)	*14*	32.8 (2.2)	*18*
Unilateral	33.5 (1.2)	*20*	33.8 (1.1)	*17*	35.5 (1.3)	*21*	34.2 (1.0)	*17*
Anaerobic threshold [ml·kg^{-1}·min^{-1}]								
Overall	16.8 (0.7)	*41*	19.7 (0.7)	*40*	18.7 (0.8)	*40*	17.4 (0.7)	*41*
Bilateral	15.5 (1.2)	*20*	19.5 (1.0)	*23*	17.6 (1.2)	*19*	17.2 (1.0)	*22*
Unilateral	18.1 (0.9)	*21*	20.0 (0.9)	*17*	19.8 (1.1)	*21*	17.6 (0.9)	*19*
O_2 pulse [ml·beat^{-1}]								
Overall	5.9 (0.4)	*37*	6.7 (0.4)	*34*	7.0 (0.4)	*35*	7.0 (0.4)	*35*
Bilateral	5.0 (0.3)	*18*	5.9 (0.3)	*17*	5.8 (0.3)	*14*	6.2 (0.4)	*18*
Unilateral	6.8 (0.6)	*19*	7.6 (0.6)	*17*	7.7 (0.6)	*21*	7.9 (0.7)	*17*
VE/VO_2								
Overall	42.2 (1.3)	*38*	38.8 (0.9)	*34*	38.6 (0.9)	*35*	37.7 (1.1)	*35*
Bilateral	44.4 (2.1)	*18*	39.1 (1.2)	*17*	39.4 (1.7)	*14*	38.4 (1.9)	*18*
Unilateral	40.3 (1.4)	*20*	38.5 (1.3)	*17*	38.0 (1.1)	*21*	36.9 (1.0)	*17*
Anaerobic fitness								
P20mean [W·kg^{-1}]								
Overall	3.5 (0.2)	*44*	3.6 (0.2)	*44*	3.4 (0.2)	*44*	3.6 (0.2)	*43*
Bilateral	3.0 (0.3)	*23*	2.9 (0.3)	*25*	2.7 (0.3)	*23*	3.0 (0.2)	*22*
Unilateral	4.1 (0.3)	*21*	4.4 (0.3)	*19*	4.2 (0.2)	*21*	4.2 (0.3)	*21*
Muscle strength								
Knee ext [Nm·kg^{-1}]†								
Overall	1.17 (0.05)	*46*	1.21 (0.05)	*44*	1.20 (0.05)	*46*	1.17 (0.05)	*44*
Bilateral	1.13 (0.07)	*24*	1.18 (0.08)	*25*	1.13 (0.08)	*24*	1.06 (0.08)	*23*
Unilateral	1.21 (0.06)	*22*	1.26 (0.06)	*19*	1.27 (0.07)	*22*	1.29 (0.06)	*21*
Hip Abd [Nm·kg^{-1}]†								
Overall	0.84 (0.04)	*46*	0.83 (0.03)	*44*	0.89 (0.04)	*46*	0.80 (0.04)	*44*
Bilateral	0.76 (0.06)	*24*	0.81 (0.05)	*25*	0.82 (0.07)	*24*	0.73 (0.05)	*23*
Unilateral	0.92 (0.05)	*22*	0.86 (0.03)	*19*	0.95 (0.04)	*22*	0.89 (0.05)	*21*

Abbreviations: Knee ext: isometric knee extensor muscle strength; Hip Abd: isometric hip abductor muscle strength; na: not assessed; GMAE: Gross Motor Ability Estimator; P20mean: mean anaerobic power; †: of the non-dominant leg.

changes in aerobic fitness were weakly related to changes in muscle strength. In children with a unilateral CP, no longitudinal relationships between fitness components were found. Changes in anaerobic fitness, and to a lesser extent changes in muscle strength, determined mobility capacity in children with a bilateral CP, while none of the fitness components were related to mobility capacity in children with a unilateral CP.

Anaerobic fitness was positively and strongly related to aerobic fitness in children with a bilateral CP. It appears that low anaerobic capacity might limit aerobic fitness, while improving capacity to achieve short duration high intensity exercise (anaerobic capacity) might contribute to a higher peak oxygen uptake. This strong relationship was also found in a cross-sectional study undertaken in adults with CP, with a weaker relationship found in adults without CP.[11] The relationship between aerobic and anaerobic fitness is in agreement with the finding that aerobic fitness can be improved through anaerobic training in children with CP.[42] In our study, the longitudinal component of the regression coefficient is indicative for the actual relationship in changes between parameters. In more detail, when exercise is performed with a gradual increase of intensity, as in the maximal aerobic exercise test, the oxygen dept that occurs with every step increase requires an anaerobic contribution to achieve a new steady state.[43] Therefore, for children with physical activity patterns that are characterized by short, intermittent activities, anaerobic training programs might also have potential for improving aerobic fitness which might eventually be beneficial to general health.[1,2]

Muscle strength appears to be a less important limiting factor for aerobic and anaerobic fitness, as indicated by weak relationships. This corresponds to the weak relationships reported in adults with CP for isometric knee muscle strength of the more impaired leg and aerobic and anaerobic fitness[11], although the relationships for muscle strength of the less impaired leg were stronger.[11] However, these conclusions were based on a combined sample of unilateral and bilateral involved adults with CP. As indicated in our study, results may differ for persons with CP with a different anatomical involvement. In addition, our study included prepubertal children in whom muscle characteristics differ from adults due to hormonal factors.[27] Our results show that VE/VO_2 relates to muscle strength in children with bilateral CP. This might be indicative for a better ventilation efficiency due to changes in muscle volume, which could be beneficial in terms of muscle strength and oxidative capacity.[45]

The lack of relationships among fitness components in children with a unilateral CP in this study cannot be compared to previous studies as these relationships have not previously been evaluated for these subgroups separately. However, in the adult study, stronger correlations among fitness components were shown for adults with CP compared to those without CP.[11] This finding was attributed to the limiting effect of muscle strength in CP. The stronger correlations for the less impaired leg might indicate that muscle strength of the less impaired leg is more important for cycling performance. This might explain the lack of

TABLE 5.3 Relations between Aerobic Fitness with Anaerobic Fitness and Muscle Strength

Aerobic fitness	VO_2peak [ml·kg^{-1}·min^{-1}]			Anaerobic threshold [ml·kg^{-1}·min^{-1}]			O_2 pulse [ml·beat^{-1}]			VE/VO_2		
	B (SE)	95% CI	*p*	B (SE)	95% CI	*p*	B (SE)	95% CI	*p*	B (SE)	95% CI	*p*
Anaerobic fitness												
P20mean [W·kg^{-1}]												
Overall	**1.79 (0.48)**	**0.85 to 2.73**	**0.000**	**0.93 (0.34)**	**0.26 to 1.60**	**0.008**	0.22 (0.14)	-0.05 to 0.49	0.112	-0.15 (0.56)	-1.27 to 0.97	0.791
Bilateral	**3.31 (0.67)**	**1.98 to 4.64**	**0.000**	**1.10 (0.47)**	**0.16 to 2.05**	**0.023**	**0.43 (0.21**	**0.00 to 0.85**	**0.049**	0.25 (0.83)	-1.40 to 1.90	0.766
Unilateral	0.52 (0.65)	-0.77 to 1.81	0.429	0.49 (0.57)	-0.63 to 1.61	0.388	0.05 (0.18)	-0.30 to 0.41	0.760	-0.07 (0.84)	-0.17 to 1.59	0.933
Muscle strength												
Knee ext [Nm·kg^{-1}]†												
Overall	1.40 (1.52)	-1.60 to 4.41	0.357	**2.52 (1.26)**	**0.02 to 5.02**	**0.048**	-0.01 (0.36)	-0.72 to 0.71	0.987	**3.97 (1.84)**	**0.32 to 7.62**	**0.033**
Bilateral	3.00 (2.07)	-1.09 to 7.10	0.149	2.56 (1.67)	-0.74 to 5.86	0.127	-0.37 (0.50)	-1.36 to 0.62	0.456	**4.93 (2.46)**	**0.07 to 9.79**	**0.047**
Unilateral	-0.11 (2.13)	-4.34 to 4.11	0.958	1.93 (1.93)	-0.19 to 5.74	0.320	0.35 (0.49)	-0.62 to 1.32	0.478	3.28 (2.67)	-1.99 to 8.55	0.221
Hip Abd [Nm·kg^{-1}]†												
Overall	**3.96 (1.95)**	**0.11 to 7.81**	**0.044**	2.30 (1.68)	-1.02 to 5.62	0.173	0.15 (0.46)	-0.76 to 1.07	0.741	**5.63 (2.41)**	**0.87 to 10.39**	**0.021**
Bilateral	5.38 (3.08)	-0.71 to 11.48	0.083	3.03 (2.31)	-1.55 to 7.61	0.192	-0.19 (0.79)	-1.74 to 1.37	0.814	**7.97 (3.52)**	**1.00 to 14.75**	**0.025**
Unilateral	3.11 (2.56)	-1.95 to 8.17	0.226	0.71 (2.52)	-4.27 to 5.69	0.778	0.34 (0.58)	-0.80 to 1.48	0.557	4.34 (3.31)	-2.20 to 10.89	0.192

Abbreviations: B: unstandardised coefficient; Knee ext: isometric knee extensor muscle strength; Hip Abd: isometric hip abductor muscle strength; †: of the non-dominant leg. Significant results are marked in bold text.

TABLE 5.4 Relations between Anaerobic Fitness and Muscle Strength

Anaerobic fitness	**P20mean [W·kg^{-1}]**		
	B (SE)	**95% CI**	***p***
Muscle strength			
Knee ext [Nm·kg^{-1}]†			
Overall	0.38 (0.19)	0.00 to 0.76	0.051
Bilateral	0.37 (0.26)	-0.14 to 0.88	0.150
Unilateral	0.44 (0.28)	-0.11 to 0.99	0.117
Hip Abd [Nm·kg^{-1}]†			
Overall	0.19 (0.24)	-0.29 to 0.67	0.431
Bilateral	0.52 (0.38)	-0.24 to 1.28	0.179
Unilateral	0.07 (0.33)	-0.58 to 0.72	0.839

Abbreviations: B: unstandardised coefficient; Knee ext: isometric knee extensor muscle strength; Hip Abd: isometric hip abductor muscle strength; **†:** *of the non-dominant leg. Significant results are marked in bold text.*

relationships between muscle strength of the more impaired leg in this study of children with a unilateral CP, with the least affected leg determining aerobic and anaerobic performance on a bicycle.

The strong longitudinal relationship between anaerobic fitness and mobility capacity indicates that improving anaerobic fitness might lead to a better mobility capacity in children with a bilateral CP. This confirms the suggestion of Bar-or et al. that peak mechanical power (i.e. anaerobic fitness) is a more important determinant of the ability to execute activities than aerobic fitness.[3] This supports the positive correlations between running sprint power and gross motor function found in a cross-sectional study including both unilateral and bilateral involved children with CP.[41] In addition, gross motor function increased following combined aerobic and anaerobic fitness training.[42]

As regards muscle strength, knee extensors were associated with a better gross motor function, which confirms previous findings.[9] The stronger association between hip abductors and walking ability confirms earlier findings on the relationship between hip abductors and walking capacity.[12] However, it is remarkable, given that gross motor function is strongly associated with the severity of motor impairment,[16] that the higher innervated knee extensors show a stronger association with GMFM than the lower innervated hip abductors, which are more severely impaired as a consequence of the motor impairment.[13] In conclusion, improving gross motor function through fitness training focused on increasing anaerobic power, and to a lesser extent through increasing muscle strength, seems to have potential in children with a bilateral CP.

Increasing anaerobic power might not contribute to improvement of gross motor function and walking capacity in children with a unilateral CP, as indicated by the lack of a relationship in this group. The differing relationships in unilateral and bilateral involved CP might explain the fact that gross motor function and walking capacity did not improve with increased knee extension and hip abduction muscle strength, since no distinction was made between

TABLE 5.5 Relations of Fitness with Mobility Capacity

	GMAE			Walking capacity		
	B (SE)	**95 %CI**	***p***	**B (SE)**	**95 %CI**	***p***
Aerobic fitness						
VO₂peak [ml·kg⁻¹·min⁻¹]						
Overall	0.063 (0.124)	-0.184 to 0.309	0.613	**0.32 (0.20)[1]**	**-0.08 to 0.71**	**0.112**
Bilateral	**0.295 (0.143)**	**0.011 to 0.579**	**0.042**	**0.52(0.22)[1]**	**0.09 to 0.96**	**0.019**
Unilateral	-0.208 (0.167)	-0.541 to 0.125	0.217	0.23 (0.27)[1]	-0.30 to 0.76	0.395
Anaerobic threshold [ml·kg⁻¹·min⁻¹]						
Overall	0.023 (0.109)	-0.193 to 0.239	0.832	0.19 (0.19)	-0.17 to 0.56	0.299
Bilateral	0.099 (0.143)	-0.186 to 0.384	0.491	0.34 (0.24)	-0.14 to 0.81	0.164
Unilateral	-0.106 (0.160)	-0.424 to 0.213	0.512	-0.04 (0.27)	-0.56 to 0.49	0.895
Anaerobic fitness						
P20mean [W·kg⁻¹]						
Overall	**2.75 (0.67)**	**1.43 to 4.07**	**0.000**	**5.4 (1.1)[1]**	**3.2 to 7.5**	**0.000**
Bilateral	**5.14 (0.90)**	**3.34 to 6.94**	**0.000**	**7.9 (1.3)[1]**	**5.4 to 10.5**	**0.000**
Unilateral	1.54 (0.91)	-0.26 to 3.34	0.093	2.5 (1.5)[1]	-0.46 to 5.4	0.097
Muscle strength						
Knee ext [Nm·kg⁻¹]†						
Overall	3.25 (1.86)	-0.43 to 6.94	0.083	3.5 (3.3)[1]	-3.1 to 10.1	0.294
Bilateral	**7.88 (2.49)**	**2.93 to 12.82**	**0.002**	8.4 (4.3)[1]	-0.1 to 17.0	0.053
Unilateral	-0.97 (2.61)	-6.14 to 4.21	0.712	1.3 (4.9)[1]	-8.4 to 11.1	0.788
Hip Abd [Nm·kg⁻¹]†						
Overall	1.01 (2.47)	-3.89 to 5.92	0.683	**12.4 (4.2)[1]**	**4.1 to 20.7**	**0.003**
Bilateral	7.65 (4.01)	-0.29 to 15.58	0.059	**27.7 (5.8)[1]**	**16.1 to 39.2**	**0.000**
Unilateral	-0.77 (3.35)	-7.44 to 5.90	0.820	5.1 (5.9)[1]	-6.5 to 16.7	0.386

Abbreviations: B: unstandardised coefficient; Knee ext: isometric knee extensor muscle strength; Hip Abd: isometric hip abductor muscle strength; [1] corrected for height; †: of the non-dominant leg. Significant results are marked in bold text.

children with bilateral or unilateral CP in these studies.[29;30;32] A previous study found better gross motor function and walking capacity in children with a unilateral CP than in children with a bilateral CP within a given GMFCS level and suggested these components to be evaluated separately for unilateral and bilateral CP.[10] While improvements in mobility capacity might be expected following anaerobic fitness training in children with a bilateral CP, this is not expected for children with a unilateral CP. A different approach is required for improving mobility capacity in children with either a unilateral or a bilateral CP.

Limitations

A limitation of this study was that isometric muscle strength of the dominant leg was not measured, while the least affected leg might determine aerobic and anaerobic performance. Another limitation was that only two muscle groups were included in the measurements.

TABLE 5.6 Multiple Random Coefficient Regression Models for Mobility Capacity in Children with Bilateral Cerebral Palsy

GMAE	B (SE)	95% CI	*p*	Walking capacity	B (SE)	95% CI	*p*
Constant	52.7 (4.6)	43.5 to 61.9	<0.001	**Constant**	5.5 (27.7)	50.0 to 61.0	0.844
P20mean	3.7 (1.1)	1.6 to 5.8	0.001	P20mean	5.9 (1.5)	2.9 to 8.8	<0.001
Knee ext†	9.1 (3.0)	3.1 to 15.2	0.004	Hip Abd†	15.2 (6.2)	2.9 to 27.4	0.016
				Height[1]	0.3 (0.2)	0.1 to 0.8	0.124

Abbreviations: B: unstandardised coefficient; Knee ext: isometric knee extensor muscle strength; Hip Abd: isometric hip abductor muscle strength; [1] as confounder; ***†:*** *of the non-dominant leg.*

Conclusions

The strong longitudinal relationship between aerobic and anaerobic fitness indicates that increasing either aerobic or anaerobic fitness corroborates with improvements in the other fitness component in children with bilateral CP only. While increasing anaerobic fitness might be beneficial for mobility capacity in children with bilateral CP, this is less likely for children with unilateral CP. Different interventions are required for improving mobility capacity in children with either a unilateral or a bilateral CP.

Perspective

There is increasing evidence that children with cerebral palsy (CP) have lower aerobic and anaerobic fitness. Similar declines have been detected in adults with CP.[22] As inactive children are more likely to become inactive adults,[33] interventions to improve fitness should start during childhood. Over the years, most training programs in children with CP have focused on increasing muscle strength. The results of the present study show that changes in anaerobic fitness strongly relate to aerobic fitness, as well as to mobility capacity in children with a bilateral CP. A focus on increasing anaerobic fitness in this group might contribute to better aerobic fitness, which is related to a better general health, in addition to an improved capacity for mobility in children with a bilateral CP. In the case of children with a unilateral CP, more research is required to reveal the limiting factors for exercise and mobility capacity that can subsequently be addressed in intervention programs.

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