Research in Developmental Disabilities 71 (2017) 70–76

Contents lists available at ScienceDirect

Research in Developmental Disabilities

journal homepage: www.elsevier.com/locate/redevdis

Body mass index and fitness in high-functioning children and adolescents with cerebral palsy: What happened over a decade?

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ARTICLE INFO

Keywords:
Cerebral palsy
Children
Adolescents
Physical fitness
Health
Rehabilitation

ABSTRACT

Background: In recent decades, improving fitness has become an important goal in rehabilitation medicine in children and adolescents with cerebral palsy (CP).
Aims: To compare body mass index (BMI), performance-related fitness, and cardiorespiratory fitness of children with CP measured in 2014 with a comparable sample from 2004.
Methods and procedures: In total, 25 high-functioning children with CP (i.e., GMFCS I–II) measured in 2004 (13 boys; mean age 13.2 (2.6) years) were matched to 25 children measured in 2014. Outcomes included body mass and BMI, muscle power sprint test (MPST), 10 × 5 m sprint test, and a shuttle run test (SRT). Data of 15 participants from 2004 (10 boys; mean age 12.6 (2.5) years) were matched and analysed for VO_2peak.
Outcomes and results: Body mass and BMI were higher (both: $p < 0.05$) in the 2014 cohort compared to the 2004 cohort. Further, performance-related fitness was better for the 2014 cohort on the MPST ($p = 0.004$), the 10 × 5 m sprint test ($p = 0.001$), and the SRT ($p < 0.001$). However, there were no differences for VO_2peak.
Conclusions and implications: In high-funcitoning children with CP, there are positive ecological time trends in performance-related fitness, but not in VO_2peak between 2004 and 2014. The substantial higher body mass and BMI is alarming and requires further investigation.

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http://dx.doi.org/10.1016/j.ridd.2017.09.021
Received 18 April 2017; Received in revised form 15 September 2017; Accepted 28 September 2017
0891-4222/

What this paper adds

In recent decades, improving fitness levels of children and adolescents with cerebral palsy (CP) has become an important goal in rehabilitation medicine. Published studies related to exercise training programs for children and adolescents with CP have shown positive effects. However, it usually takes time for scientific results to be implemented in clinical practice. This study has the unique opportunity to study, with an timeframe of 10 years, if body mass, BMI and fitness levels of children with CP has been changed. We were able to compare two datasets collected in a similar way in the same country (and regions) in children and adolescents with CP. These datasets have the same outcomes on body mass and BMI, performance-related fitness and VO_2peak. The present study shows positive ecological time trends in performance-related fitness in children and adolescents with CP between 2004 and 2014. However, the higher body mass and BMI, and the unchanged VO_2 peak requires further investigation.

1. Introduction

Improving physical fitness has become an important aspect during rehabilitation. Over the last decades, the number of studies on physical fitness in children and adolescents with cerebral palsy (CP) has grown exponentially. It is recommended that all children with CP should engage, to the extent they are able, in aerobic, anaerobic and muscle strengthening activities. (Maltais, Wiart, Fowler, Verschuren, & Damiano, 2014; Verschuren, Peterson, Balemans, & Hurvitz, 2016) It is generally acknowledged that children and adolescents with CP can be trained according to general exercise physiological training principles, without exacerbating spasticity. (Darrah, Fan, Chen, Nunweiler, & Watkins, 1997)

Physical fitness can be divided into subcomponents including performance-related fitness and cardiorespiratory fitness. Performance-related fitness is the combined result of coordinated exertion with a variety of physiological functions. (Åstrand, 2003) Coordination, speed, agility, and short-term muscle power are often described as outcome measures related to performance. Cardiorespiratory fitness, generally expressed as peak oxygen uptake (VO_2peak), is a strong predictor for cardiovascular disease later in life. (Ruiz et al., 2009)

In the typically developing population, previous ecological time trend studies showed that both performance-related fitness and cardiorespiratory fitness has declined in children and adolescents over recent decades. (Boddy, Fairclough, Atkinson, & Stratton, 2012; Dos Santos et al., 2015; Dyrstad, Aandstad, & Hallén, 2005; Huotari, Nupponen, Laakso, & Kujala, 2010) Performance on both 20-m Shuttle Run Test (SRT) (Boddy et al., 2012) and 10×5 m sprint test have decreased. (Dos Santos et al., 2015) In addition, running performance on a time trial decreased by 10% and 6% for boys and girls, respectively, in Finnish adolescents between the 1980s and 2000s. (Huotari et al., 2010) Moreover, VO_2 peak decreased by 8% in Norwegian adolescents from 1985 to 2002. (Dyrstad et al., 2005)

Weight gain and the rising obesity prevalence among children and adolescents is becoming a serious health problem worldwide. (Ng et al., 2014) Physical fitness levels are negatively associated with overweight. (Ruiz et al., 2009) Body weight and body mass index (BMI) increased by 7% and 6%, respectively, in Norwegian adolescents from 1985 to 2002. (Dyrstad et al., 2005) Moreover, BMI has been shown to be inversely associated with running performance, indicating higher BMIs over time may lead to poorer fitness and running capacities. (Huotari et al., 2010) Since children and adolescents with CP have lower performance-related fitness and cardiorespiratory fitness compared to children who are typically developing, (Balemans et al., 2013; Verschuren & Takken, 2010) they are thought to be at increased risk for overweight.

A large number of studies have shown positive effects of exercise training in children with CP on performance-related fitness (Verschuren, Takken et al., 2007 Verschuren, Ketelaar et al., 2007) and cardiorespiratory fitness. (Butler, Scianni, & Ada, 2010) These insights in the positive effects of exercise training should ideally lead to implementation in clinical practice. The aim of the current study is to compare body mass and BMI, performance-related fitness, and cardiorespiratory fitness in a convenience sample of children with CP measured in 2014 with a comparable sample from 2004.

2. Methods

For the current study, data collected in 2014 (Zwinkels et al., 2015) were compared to two datasets from two different studies performed in 2004. (Verschuren, Takken, Ketelaar, Gorter, & Helders, 2006; Verschuren, Takken et al., 2007; Verschuren, Ketelaar et al., 2007) Data collection was administered similarly, since two researchers (OV, TT) involved in the 2004-studies supervised data collection in 2014.

2.1. Setting and participants

All participants from both 2004 and 2014 samples were recruited from several schools for special education in the Netherlands. Children and adolescents were included if they were diagnosed with spastic CP, classified at GMFCS level I or II, and between the age of 7–18 years. Data of the 2014 study were used and matched with the data collected in 2004 according to sex, GMFCS-level and height up to three centimetre difference. These characteristics are most related to both performance-related fitness and cardiorespiratory fitness. (Verschuren & Takken, 2010) Height was used instead of age, because its more discriminative value for physical fitness in this population. Matching was done for the two different datasets from 2004 to compose separate databases containing either body mass, BMI and performance-related fitness, (Verschuren, Takken et al., 2007 Verschuren, Ketelaar et al., 2007) and cardiorespiratory fitness. (Verschuren et al., 2006)

To assess differences in body mass and BMI, and performance-related fitness, data of 68 and 25 participants were available, collected in 2004 and 2014 respectively. We were able to match all 25 children with CP measured in 2014 to a similar sample of 25 participants from 2004. To assess differences in cardiorespiratory fitness, data of 24 and 25 children were available, collected in 2004 and 2014 respectively. Due to a sex and height differences, matching resulted in a sample of 30 participants in total; 15 measured in 2004 and 15 in 2014.

Ethics approval and administrative site approvals were granted by the Medical Ethical Committee of UMC Utrecht in the Netherlands. Additionally, all parents, and participants from 12 years of age, provided informed consent.

2.2. Anthropometry

Prior to testing, each child was weighted to the nearest 100 g on electronic scales (Seca, Hamburg, Germany). Height was measured while the child was standing against a wall. The BMI was calculated as weight in kilograms divided by height in meters squared. To control for differences in height, Z-scores of BMI for height were calculated according to Dutch reference values. (Talma, Schonbeck, Bakker, Hirasing, & van Buuren, 2010)

2.3. Performance-related fitness

2.3.1. Anaerobic performance

Mean and peak power were measured for anaerobic performance derived from the Muscle Power Sprint Test (MPST) as previously described by Verschuren, Takken, Ketelaar, Gorter, and Helders, (2007) Participants were instructed to complete six 15-m runs at maximum pace with a 10 s rest in between each run. Power output for each sprint was calculated using body mass and sprint time, where: power = (body mass × distance^2)/time^3. Peak power was defined as the highest calculated power, while mean power was defined as average power over the six sprints.

2.3.2. Agility

The 10 × 5 m sprint test was performed to measure agility. Participants had to sprint 10 times as fast as possible between two lines five meter apart without rest. This is a reliable field test to measure agility in children with CP. (Verschuren, Ketelaar et al., 2007)

2.3.3. Aerobic performance

Aerobic performance was measured using the achieved level on the 10 m SRT developed for children and adolescents with CP, classified with GMCS-level I and II. This test is a reliable and valid measure in children and adolescents with CP as previously described by Verschuren et al. (2006) The SRT is a field test in which a child runs or walks between two markers delineating the respective course of 10 m at a set incremental speed determined by a signal every minute. The children have to adjust their running or walking pace to the beep-signals, until they fail to reach the line two times in a row, despite encouragements. The starting speeds for the tests are 5 and 2 km/h for participants who are classified at GMFCS levels I and II, respectively, and the speeds are increased by 0.25 km/h every minute. The last completed level, accurate to a half shuttle, was recorded and used for analysis. Heart rate was measured continuously with a heart rate monitor throughout the test. The SRT has shown to be valid, reliable and sensitive to change in children with CP. (Verschuren et al., 2006; Verschuren, Takken et al., 2007 Verschuren, Ketelaar et al., 2007)

2.4. Cardiorespiratory fitness

Cardiorespiratory fitness was measured during the 10-m SRT by obtaining VO_2peak. Participants wore a calibrated mobile gas analysis system of Cortex Metamax (Samcon bvba, Melle, Belgium). This system is valid and reliable for measuring ventilator parameters during exercise. (Medbø, Mamen, Welde, von Heimburg, & Stokke, 2002) It consists of a facemask, transmitting unit attached to a harness containing oxygen and carbon dioxide analysers, and a receiving unit. Metabolic stress test software (Metasoft) was used to measure oxygen uptake (VO_2), carbon dioxide production, minute ventilation, respiratory exchange ratio (RER = VCO_2/VO_2), and heart rate (HR). Subjective criteria were used to determine if a test was maximal; signs of intense effort such as unsteady running pattern, sweating and facial flushing.

2.5. Statistical analysis

Statistical comparisons between children and adolescents with CP measured in 2004 and 2014 were tested using an independent sample T-Test. In addition, differences between GMFCS-level I and II were tested ($P = 0.05$). All statistical analyses were performed using SPSS for Windows (version 21.0, SPSS Inc, Chicago, IL.)

3. Results

For body mass, BMI and performance-related fitness, participant characteristics of 25 children and adolescents with CP from both the 2004 and 2014 sample are presented in Table 1. Sex and GMFCS-levels were equally divided; 13 boys and 15 classified at GMFCS-level I.

Table 1
Participant characteristics for anthropometry and performance-related fitness.

Participants	Variable	2004-sample				2014-sample				
		n	Mean	SD	Range	n	Mean	SD	Range	*p*
Total	Age (y)	25	13.2	2.6	8–17	25	14.2	2.9	8–18	0.205
	Height (cm)	25	158.2	14.2	133–183	25	161.2	11.5	140–184	0.406
	Weight (kg)	25	51.2	13.5	33–78	25	64.6	21.4	34–116	.010*
	BMI (kg/m^2)	25	20.2	3.8	15.4–29.7	25	24.3	5.6	17.5–39.0	.004*
	BMI for height [a]	25	0.69	1.5	−1.39-3.83	25	1.79	1.36	−0.65-3.93	.009*
GMFCS I	Age (y)	15	13.9	2.5	8–17	15	14.2	3.2	8–18	0.732
	Height (cm)	15	163.9	12.5	141–183	15	163.8	12.4	140–184	0.970
	Weight (kg)	15	56.9	12.0	37–78	15	72.5	22.7	40–116	.026*
	BMI (kg/m^2)	15	21.2	4.4	16.5–29.7	15	26.5	5.7	18.3–39.0	.008*
	BMI for height [a]	15	0.81	1.76	−1.26-3.83	15	2.40	1.17	.46−3.93	.007*
GMFCS II	Age (y)	10	12.2	2.4	9–17	10	14.1	2.6	9–18	0.100
	Height (cm)	10	149.5	12.7	133–170	10	157.4	9.3	140–169	0.128
	Weight (kg)	10	42.5	11.0	33–66	10	52.7	12.3	34–74	0.065
	BMI (kg/m^2)	10	18.7	2.1	15.4–22.8	10	21.0	3.3	17.5–27.9	0.079
	BMI for height [a]	10	0.52	1.05	−1.39-1.91	10	0.88	1.13	−0.65-2.86	0.474

SD: Standard Deviation, GMFCS: Gross Motor Function Classification System, BMI: Body Mass Index.
[a] Z-score.
* $p < 0.05$.

3.1. Anthropometry

A significantly higher body mass and BMI were found in the 2014 cohort for the total group ($p = 0.010$; $p = 0.004$) and GMFCS-level I ($p = 0.026$; $p = 0.008$). Body mass gained with 26% and 27%, and BMI was 20% and 25% higher for the total group and GMFCS-level I respectively. The same applies for the calculated BMI for height Z-scores, as shown in Table 1.

3.2. Performance-related fitness

Table 2 shows the differences for performance-related fitness. Both mean and peak power on the MPST are significantly higher, respectively 99% and 87%, over a decade ($p=0.004$; $p=0.006$). In addition, children with CP measured in 2014 perform significantly better (23%) on agility, in the total group ($p=0.001$), and for GMFCS-level I and II respectively ($p=0.007$; $p=0.003$). The same

Table 2
Performance-related fitness.

Participants	Variable	2004-sample				2014-sample				
		n	Mean	SD	95% CI	n	Mean	SD	95% CI	*p*
Total	Anaerobic performance									
	Mean power (W)	25	102.4	77.7	70–134	25	203.8	148.4	142–265	.004*
	Peak power (W)	25	125.8	96.2	86–166	25	235.7	166.1	167–304	.006*
	Agility									
	10 × 5 (s)	25	33.7	9.6	29.7–37.6	25	25.8	5.1	23.7–27.9	≤.001*
	Aerobic performance									
	Achieved level on SRT	25	7.6	4.5	5.7–9.4	25	12.7	5.1	10.6–14.8	≤.001*
GMFCS I	Anaerobic performance									
	Mean power (W)	15	145.7	70.1	107–185	15	271.2	157.2	184–358	.009*
	Peak power (W)	15	179.9	86.5	132–227	15	311.9	174.7	215–409	.014*
	Agility									
	10 × 5 (s)	15	28.8	4.6	26.3–31.3	15	23.8	4.9	21.1–26.5	.007*
	Aerobic performance									
	Achieved level on SRT	15	6.3	4.0	4.1–8.5	15	11.3	5.4	8.2–14.1	.009*
GMFCS II	Anaerobic performance									
	Mean power (W)	10	37.4	24.8	20–55	10	102.6	37.3	76–129	≤.001*
	Peak power (W)	10	44.7	29.2	24–66	10	121.5	43.4	90–153	≤.001*
	Agility									
	10 × 5 (s)	10	41.0	10.7	33.3–48.6	10	28.9	3.8	26.2–31.7	.003*
	Aerobic performance									
	Achieved level on SRT	10	9.4	4.7	6.2–12.8	10	15.0	3.9	12.2–17.7	.011*

SD: Standard Deviation, CI: Confidence Interval, GMFCS: Gross Motor Function Classification System. SRT: Shuttle Run Test.
* $p < 0.05$.

Table 3
Participant characteristics for cardiorespiratory fitness.

Participants	Variable	2004-sample				2014-sample				
		n	Mean	SD	Range	n	Mean	SD	Range	p
Total	Age (y)	15	12.6	2.5	7–17	15	12.7	2.8	8–18	0.917
	Height (cm)	15	154.5	13.9	130–175	15	157.0	10.9	140–176	0.595
GMFCS I	Age (y)	8	11.9	2.8	7–16	8	12.0	2.7	8–16	0.945
	Height (cm)	8	154.8	15.1	130–175	8	158.0	12.0	140–176	0.643
GMFCS II	Age (y)	7	13.4	2.0	11–17	7	13.5	2.9	9–18	0.936
	Height (cm)	7	154.3	13.6	135–170	7	155.9	10.3	140–166	0.812

SD: Standard Deviation, GMFCS: Gross Motor Function Classification System.

applies for aerobic performance as shown in Table 2. The 2014 cohort performed 67% better, measured with achieved level on the SRT.

3.3. Cardiorespiratory fitness

Participant characteristics of 15 children and adolescents with CP from both samples are presented in Table 3. Sex and GMFCS-levels were equally divided; 10 boys and 8 classified at GMFCS-level I. The SRTs of both samples were quite similar regarding peak heart rate (198 (5) bpm; 183 (18) bpm) and RER (1.05 (0.11); 1.07 (0.10)) for the 2004 and 2014 sample respectively. As indicated in Table 4, no differences were found in VO_2peak, despite of a better performance on the SRT ($p = 0.001$). No differences were found for absolute (l/min) and relative (ml/kg/min) VO_2-peak respectively in the total group ($p = 0.408$; $p = 0.315$), neither for GMFCS-level I ($p = 0.312$; $p = 0.741$), and GMFCS-level II ($p = 0.921$; $p = 0.246$).

4. Discussion

This study compared body composition, performance-related fitness, and cardiorespiratory fitness in a representative cohort of high-functioning children with CP, GMFCS-level I and II, measured in 2014 with a comparable cohort from 2004. In the 2014 cohort, body mass and BMI were higher compared to the 2004 cohort. In the contrary, performance-related fitness was better for the 2014 cohort with regards to agility and both anaerobic and aerobic performance, as compared to the 2004 cohort. Cardiorespiratory fitness however, did not differ between 2004 and 2014.

Although this is the first observational study to analyse fitness trends in children and adolescents with CP, a limitation of our study is the relatively small sample size measured cross-sectionally with a considerable large age range (7–18 years). Exercise training programs for children with CP have become a contemporary focus of intervention, (Butler et al., 2010) especially at schools for special education in the Netherlands. Therefore, the results reported may not be representative for children with CP in other countries. Although several dependent outcome measures were analysed, the two datasets differ to the extent that we assume no type I error occurred.

Body mass and BMI were 26% and 20% higher respectively in the 2014 cohort. Compared to differences of 6% and 7% in the typically developing population, this is substantial. (Dyrstad et al., 2005) Especially when taking into account that children who develop typically and children with CP have similar body compositions. (Bell & Davies, 2010) Although BMI is commonly used and provides the most useful measure to estimate the prevalence of overweight, BMI does not distinguish between weight associated with muscle mass and weight associated with fat mass. (WHO, 2000) Since strength training may lead to hypertrophy in children and

Table 4
Cardiorespiratory fitness on the 10-m SRT.

Participants	Variable	2004-sample				2014-sample				
		n	Mean	SD	95% CI	n	Mean	SD	95% CI	p
Total	Achieved level on SRT	15	9.2	2.9	7.6–10.8	15	14.2	4.8	11.6–16.9	≤.001*
	VO_2peak (l/min)	15	1.87	0.46	1.62–2.13	15	2.07	0.78	1.64–2.50	0.408
	VO_2peak (ml/kg/min)	15	40.9	8.4	36.3–45.5	15	37.5	10.4	31.5–43.5	0.315
GMFCS I	Achieved level on SRT	8	7.9	2.4	5.9–9.9	8	13.1	6.0	8.1–18.2	.040*
	VO_2peak (l/min)	8	1.94	0.42	1.59–2.29	8	2.33	0.96	1.52–3.13	0.312
	VO_2peak (ml/kg/min)	8	41.9	6.2	36.7–47.1	8	40.2	12.6	29.7–50.8	0.741
GMFCS II	Achieved level on SRT	7	10.6	2.9	7.9–13.3	7	15.5	2.6	13.1–17.9	.006*
	VO_2peak (l/min)	7	1.79	0.52	1.31–2.28	7	1.77	0.37	1.42–2.11	0.921
	VO_2peak (ml/kg/min)	7	39.7	10.8	29.8–49.7	7	34.3	5.0	29.7–38.9	0.246

SD: Standard Deviation, CI: Confidence Interval, GMFCS: Gross Motor Function Classification System, SRT: Shuttle run test, VO_2peak: peak oxygen uptake.
* $p < 0.05$.

adolescents with CP, (Gillett, Boyd, Carty, & Barber, 2016) they may have gained weight due to increased muscle mass in the recent decade. This could well have caused an overestimation of the weight-gain, but nonetheless the increase in body mass and BMI is substantial. Therefore it can cause severe problems for longterm health as it increases cardiovascular risk. (Parrett, Valentine, Arngrimsson, Castelli, & Evans, 2011)

Compared to the 2004 cohort, VO_2peak values remain similar in children and adolescents with CP despite the higher performance on SRT. This discrepancy underlines the fact that VO_2peak and performance on SRT measure different constructs; (Balemans, Van Wely, Blonk, Becher, & Dallmeijer, 2015) health and performance related fitness respectively. Several training studies performed between 1997 and 2007 found significant improvements in cardiorespiratory fitness ranging from 20 to 38%. (Butler et al., 2010) However, an improvement of only 11% in VO_2peak was found in a study performed in 2014. (Slaman et al., 2014) In addition, a recent intervention study conducted in the Netherlands in children with CP showed no significant effect in cardiorespiratory fitness following a physical activity stimulation program consisting of fitness training, counselling and home-based therapy. (Van Wely, Balemans, Becher, & Dallmeijer, 2014) Possibly, standard healthcare has developed in such a way that currently baseline fitness levels have so much increased that consequently no significant training effect was induced.

Verschuren et al. provided international reference values for performance-related fitness in children and adolescents with CP, GMFCS level I and II, in 2010. (Verschuren et al., 2010a; Verschuren et al., 2010b) With regards to the current study, corresponding reference values of Verschuren et al. perfectly match the 2004 cohort. This implies that reference scores for mean power on the MPST, 10 × 5, and aerobic performance on the SRT, possibly underestimate performance outcomes of children and adolescents with CP today. Although the study population of Verschuren et al. was much larger than our study, reference values might not be up-to-date anymore.

In conclusion, the present study shows positive ecological time trends in performance-related fitness in high-functioning children and adolescents with CP over a decade. This seems promising, given the fact that clinical implementation typically takes up to 20 years. However, the higher body mass and BMI, as well as the unchanged cardiorespiratory fitness require further investigation. Future studies should consist of standardized outcome measures including waist circumference and body fat percentage measurements.

Funding

This work was supported by the Dr. W.M. Phelps Foundation, and by an unconditional grant of the Dutch Organization of Health Research (ZONMW) [grant number 525001005].

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