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Habitual physical activity and cardiometabolic risk factors in adults with cerebral palsy

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ABSTRACT

Adults with cerebral palsy (CP) are known to participate in reduced levels of total physical activity. There is no information available however, regarding levels of moderate-to-vigorous physical activity (MVPA) in this population. Reduced participation in MVPA is associated with several cardiometabolic risk factors. The purpose of this study was firstly to compare levels of sedentary, light, MVPA and total activity in adults with CP to adults without CP. Secondly, the objective was to investigate the association between physical activity components, sedentary behavior and cardiometabolic risk factors in adults with CP. Adults with CP ($n = 41$) age 18–62 yr (mean ± SD = 36.5 ± 12.5 yr), classified in Gross Motor Function Classification System level I ($n = 13$), II ($n = 18$) and III ($n = 10$) participated in this study. Physical activity was measured by accelerometry in adults with CP and in age- and sex-matched adults without CP over 7 days. Anthropometric indicators of obesity, blood pressure and several biomarkers of cardiometabolic disease were also measured in adults with CP. Adults with CP spent less time in light, moderate, vigorous and total activity, and more time in sedentary activity than adults without CP ($p < 0.01$ for all). Moderate physical activity was associated with waist-height ratio when adjusted for age and sex ($\beta = -0.314$, $p < 0.05$). When further adjustment was made for total activity, moderate activity was associated with waist-height ratio ($\beta = -0.538$, $p < 0.05$), waist circumference ($\beta = -0.518$, $p < 0.05$), systolic blood pressure ($\beta = -0.592$, $p < 0.05$) and diastolic blood pressure ($\beta = -0.636$, $p < 0.05$). Sedentary activity was not associated with any risk factor. The findings provide evidence that relatively young adults with CP participate in reduced levels of MVPA and spend increased time in sedentary behavior, potentially increasing their risk of developing cardiometabolic disease.

1. Introduction

Although cerebral palsy (CP) is a non-progressive disorder, it is well reported that adults with CP experience a number of secondary conditions with age. These include pain, fatigue, stiffness, and poor balance (Opheim, Jahnsen, Olsson, & Stanghelle, 2009; Van Der Slot et al., 2012), and can lead to a decline in physical functioning and loss of mobility from early adulthood. Between 30% and 52% of adults with CP reported experiencing deterioration in walking function (Bottos, Feliciangeli, Sciuto,

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Gericke, & Vianello, 2001; Opheim et al., 2009). Loss of mobility is most commonly observed between the age of 20 and 40 years (Bottos et al., 2001). Deterioration in physical functioning over time may lead to difficulties performing everyday activities and potentially an inactive lifestyle.

Only two studies have objectively measured physical activity in adults with CP to date, with conflicting results (Nieuwenhuijsen et al., 2009; van der Slot et al., 2007). Adults with unilateral spastic CP were reported to be as active as their able-bodied peers (van der Slot et al., 2007), whereas adults with bilateral spastic CP were less active than their able-bodied peers (Nieuwenhuijsen et al., 2009). Gross motor function was a strong predictor of physical activity in adults with bilateral CP (Nieuwenhuijsen et al., 2009). Differences in the gross motor function between samples may therefore explain the discrepancy in results.

Although these studies reported levels of total physical activity in adults with CP, information about time spent in individual domains of activity, such as sedentary behavior, light activity (LPA) and moderate-to-vigorous activity (MVPA), is not available. Decreased levels of MVPA and increased sedentary behavior are independently associated with risk factors for cardiovascular disease (CVD) and type II diabetes mellitus (T2DM), including obesity, dyslipidemia, hypertension, insulin resistance, hyperglycemia, and inflammatory markers (Healy, Matthews, Dunstan, Winkler, & Owen, 2011; Loprinzi et al., 2013; Luke, Dugas, Durazo-Arvizu, Cao, & Cooper, 2011; Nelson et al., 2013). The current American College of Sports Medicine (ACSM) guidelines recommend that adults accumulate 150 min of moderate activity (MPA) or 75 min of vigorous activity (VPA), in bouts of at least 10 min, per week to reduce their risk of CVD and premature mortality (Garber et al., 2011). The potentially increased risk of adults with CP developing T2DM or CVD, as a result of inactivity, has led to comparisons to people with spinal cord injury – a population known to have insulin resistance, dyslipidemia, and an elevated presence of T2DM (Bauman, 2009). Furthermore, a recent study reported that reduced MPA and increased sedentary behavior are associated with an increased risk of the metabolic syndrome in adults with impaired mobility (Peterson, Al Snih, Stoddard, Shekar, & Hurvitz, 2013). Despite this, no study has investigated habitual levels of MVPA and their association with cardiometabolic risk factors in adults with CP.

The purpose of this study was two-fold. The first objective was to compare levels of physical activity and sedentary behavior between adults with and without CP. The second objective was to examine the relationship between physical activity components, sedentary behavior and cardiometabolic risk factors in adults with CP.

2. Materials and methods

2.1. Participants

Adults with CP ($n = 41$), age 18–62 yr (mean $\pm$ SD = 36.5 $\pm$ 12.5 yr), classified in level I–III of the Gross Motor Function Classification System (GMFCS) participated in this study. This study was limited to ambulatory individuals only as accelerometers are unable to quantify physical activity in wheelchair users (Hiremath & Ding, 2011). Participants were recruited from a national centre that provides services to people with a disability and through general practitioners (GPs) nationwide. The database of the centre was searched for eligible adults, resulting in 263 letters and study invitations being sent to potential participants. Letters were sent to 1367 GPs asking them to pass on information leaflets and study invites to clients who were eligible to participate. Physical activity data from age- and sex-matched adults without CP was obtained from an institutional database of physical activity control data that was collected between 2009 and 2013. Adults with a severe intellectual disability and pregnant women were excluded from participating in this study. Participants were informed of the testing procedures before written informed consent was obtained. In the case of participants with a mild to moderate intellectual disability, their guardians also provided written informed consent. Ethical approval for this study was granted by the University of Dublin's Faculty of Health Sciences' ethics committee and the Central Remedial Clinic's ethics committee.

2.2. Procedures

Participants were classified according to the GMFCS and according to type of motor abnormality and anatomical distribution as defined by the Surveillance of Cerebral Palsy in Europe (Rosenbaum et al., 2007). Information was also obtained from participants regarding their history of CVD and T2DM and current use of medication.

Height, body mass, body mass index (BMI), waist circumference (WC), waist-hip ratio (WHR), and waist-height ratio (WHtR) were measured in participants. WC was measured, on bare skin, to the nearest 0.1 cm midway between the lower rib margin and the iliac crest at the end of gentle expiration. HC was measured to the nearest 0.1 cm at the end of gentle expiration around the maximum circumference of the buttocks. The mean of two measurements was used for both WC and HC. Overweight and obesity were identified as a BMI $\geq$ 25 kg m^{-2} and $\geq$30 kg m^{-2}, respectively. Central obesity was defined as WC $\geq$ 80 cm for women and $\geq$94 cm for men.

Blood pressure was measured from the right arm or the least affected side, in the case of significant asymmetry, using the Omron 705 IT BP monitor. The Omron 705 IT has demonstrated excellent validity in adults under the British Hypertension Society criteria (El Assaad, Topouchian, & Asmar, 2003). The appropriate cuff size was selected for the participant based on their mid-arm circumference and placed so that the lower edge was 3 cm above the elbow crease and the bladder was centred over the brachial artery. Participants rested in a seated position with their back supported for at least 5 min before three measurements were taken at a 1–2 min interval. The average of the last two measurements was used in data analysis.

Blood was drawn following an overnight (10 h) fast and processed according to standard procedures in the Biochemistry Department, St. James's Hospital, Dublin. Participants were allowed to drink water during the fast and medications for cardiovascular stability were permitted (i.e. anti-hypertensive medications). Insulin was measured by electrochemiluminescence immunoassay (Elecsys Insulin Assay, Roche Diagnostics GMBH). Enzymatic, colorimetric assays (Roche/Hitachi cobas c systems) were used to measure fasting glucose, total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C) and triglycerides. TC/HDL-C ratio was calculated as TC divided by HDL-C. Low-density lipoprotein cholesterol (LDL-C) was calculated using the Friedewald equation (Friedewald, Levy, & Fredrickson, 1972). High performance liquid chromatography (Arkray/Adams A1c HA-8160 Analyser System) was used to measure glycated haemoglobin (HbA_{1c}) and c-reactive protein (CRP) was measured by particle enhanced immunoturbidimetric assay (Roche/Hitachi cobas c systems). High risk CRP was categorized as $>0.3\ mg\ dL^{-1}$ (Pearson et al., 2003). 25-Hydroxy vitamin D (25OHD) was measured on the API 4000 LC/MS/MS system (Norwolk, Connecticut). The Homeostasis Model Assessment index (HOMA-IR) (Matthews et al., 1985) was used to evaluate insulin resistance. The metabolic syndrome was defined according to the most recent joint interim statement (Alberti et al., 2009), i.e. the presence of three or more of the following: (1) central obesity, (2) elevated triglycerides ($\geq$150 mg/dL [1.7 mmol L^{-1}]) or drug treatment for elevated triglycerides, (3) reduced HDL-C (<40 mg/dL [1.0 mmol L^{-1}] in men; <50 mg/dL [1.3 mmol L^{-1}] in women) or drug treatment for reduced HDL-C, (4) elevated blood pressure (systolic $\geq$ 130 and/or diastolic $\geq$ 85 mm Hg) or antihypertensive drug treatment, and (5) elevated fasting glucose ($\geq$100 mg/dL) or drug treatment for elevated glucose.

Physical activity was measured using the RT3 accelerometer (Stayhealthy, Inc.). The following procedure was used to collect physical activity data in adults with and without CP. All participants were asked to wear the RT3 for 7 days on their right hip (or least affected side in the case of significant asymmetry) in the midaxillary line. Participants were told to wear the RT3 for waking hours and to remove it only for bathing and swimming. Participants were asked to record the times that they removed the monitor and the activities they completed while not wearing the monitor. Vector magnitude count data was collected in 1-min epochs.

Valid activity data was defined as having at least four days data, of at least 10 h wear time per day (Ward, Evenson, Vaughn, Rodgers, & Troiano, 2005). Sedentary activity was defined as $<100\ counts{\cdot}min^{-1}$, light activity (LPA) was defined as 100–984 $counts{\cdot}min^{-1}$, moderate activity (MPA) was defined as 984–2341 $counts{\cdot}min^{-1}$, vigorous activity (VPA) was defined as $>2341\ counts{\cdot}min^{-1}$ (Rowlands, Thomas, Eston, & Topping, 2004). Data is presented as time spent in light, moderate and vigorous activity accumulated in 1-min intervals, percentage time spent in sedentary activity (i.e. minutes spent in sedentary activity/total wear time), and mean activity counts per minute ($counts{\cdot}min^{-1}$). Time spent in MVPA accumulated in 10-min bouts was also calculated. One minute of activity below the moderate activity count threshold was allowed for before the bout was considered to be ended. Finally the percentage of adults with and without CP meeting the ACSM recommendation was calculated.

2.3. Data analysis

Statistical analysis was performed using IBM SPSS Statistics (version 19). The distribution of the data was checked for normality by the Kolmogorov–Smirnov test. The logarithm function was applied to HOMA-IR, TC/HDL-C ratio and 25OHD to transform this data to a normal distribution. Means and standard deviations were computed for each of the normally distributed continuous variables. Medians and interquartile ranges were computed for skewed data. Prevalence data is presented as percentages.

Differences between continuous variables with a normal distribution were determined by independent *t*-tests and one-way analysis of variance (ANOVA). Differences between continuous variables with a skewed distribution were determined by Mann–Whitney *U* tests and Kruskal–Wallis one-way analysis of variance. Pearson's χ^2 test was used for comparison of independent groups of categorical data.

Multiple linear regression was used to investigate the association between cardiometabolic risk factors (i.e. BMI, WC, WHtR, WHR, systolic blood pressure, diastolic blood pressure, TC, HDL-C, TC/HDL-C ratio, LDL-C, triglycerides, plasma glucose, HbA_{1c}, HOMA-IR, 25OHD) and physical activity components (percentage time in sedentary behavior, LPA, MPA, VPA, MVPA, mean $counts{\cdot}min^{-1}$). Collinearity was examined using variance inflation factors. All analyses were controlled for age and sex.

To avoid multicollinearity, each independent variable (i.e. percentage time in sedentary behavior, LPA, MPA, VPA, MVPA, and mean $counts{\cdot}min^{-1}$) was entered in separate analyses. When systolic or diastolic blood pressure was the dependent variable of interest the analysis was additionally controlled for anti-hypertensive medication (i.e. self-report of taking any hypertension lowering medication coded as 1 if yes or 0 if no). When TC, HDL-C, LDL-C, or TC/HDL-C ratio was the dependent variable of interest the analysis was also additionally controlled for drug therapy (i.e. self-reported taking of any cholesterol medication coded as 1 if yes or 0 if no). These analyses were repeated additionally controlling for total physical activity (mean $counts{\cdot}min^{-1}$). Variance inflation factors <5 suggested that multicollinearity was not an issue.

Logistic regression was conducted to investigate the association between the metabolic syndrome, high risk CRP (dependent variables) and each physical activity component (independent variables). Analyses were initially controlled for age and sex before additionally controlling for total activity. Statistical significance was set at $p < 0.05$.

Table 1
Participants' physical and demographic characteristics by Gross Motor Function Classification System level.

	Total ($n = 41$) n (%)	GMFCS level I ($n = 13$) n (%)	GMFCS level II ($n = 18$) n (%)	GMFCS level III ($n = 10$) n (%)
Male	19 (46.3)	9 (69.2)	7 (38.9)	3 (30.0)
Diagnostic classification				
Spastic cerebral palsy	37 (90.2)	13 (100.0)	14 (77.8)	10 (100.0)
Unilateral	15 (40.5)	10 (76.9)	4 (22.2)	1 (10.0)
Bilateral	22 (59.5)	3 (23.1)	10 (55.6)	9 (90.0)
Other[a]	4 (9.8)	0 (0.0)	4 (22.2)	0 (0.0)

[a] Data from non-spastic forms of CP were combined to form one group due to the small number of participants with ataxic, dystonic, or choreoathetoid CP.

Table 2
Time spent in sedentary behavior, light, moderate, vigorous, moderate-to-vigorous activity, and mean counts·min^{-1} per day for adults with cerebral palsy by Gross Motor Function Classification System level.

	GMFCS level I		GMFCS level II		GMFCS level III		Total		p value
	M	SD	M	SD	M	SD	M	SD	
Sedentary behavior (min)	505.3	89.7	506.1	98.3	579.0	85.2	523.6	95.8	0.1082
Sedentary behavior (% of total wear-time)	61.95	9.87	60.95	9.79	69.17	10.35	63.27	10.28	0.1082
Light activity (min)	246.8	66.8	282.2	70.1	240.2	78.4	260.7	72.0	0.2411
Moderate activity (min)	45.5	17.5	37.7	28.0	16.2	14.0	33.3[a]	36.4	0.0105
Vigorous activity (min)	14.7[a]	27.4	4.3	3.1	1.2[a]	5.6	5.2[a]	7.4	0.0280
Mod-to-vig activity (min)	27.4	21.6	6.5[a]	17.0	0.0[a]	0.5	6.1[a]	23.4	0.0009
Mean counts·min^{-1}	278.7	122.6	214.3	82.5	147.0	74.3	218.3	105.4	0.0085

[a] Variable not normally distributed, data presented as median (IQR). Mod-to-vig, moderate-to-vigorous.

3. Results

The characteristics of participants with CP are presented in Table 1. Both groups (i.e. adults with and without CP) wore the RT3 for a median (IQR) of 7.0 (1.0) days. Adults with CP wore the RT3 for a median (IQR) time of 840.5 (88.5) min per day; adults without CP wore the RT3 for a mean time of 841.2 (59.3) min per day. There was no significant difference in wear time between groups.

3.1. Physical activity and sedentary time in adults with and without CP

Time spent in MPA, VPA, and MVPA, and mean counts·min^{-1} differed across GMFCS levels I, II and III, respectively (see Table 2). Post hoc pairwise comparisons revealed that adults in level I spent more time in VPA and MVPA than adults in level II, and more time in MPA, VPA, MVPA and total activity (mean counts·min^{-1}) than adults in level III ($p < 0.01$ for all). Adults in level II spent more time in MPA than adults in level III ($p < 0.05$). Adults in level III spent more time in sedentary behavior than adults in level II ($p < 0.05$). There were no other differences in physical activity components between GMFCS levels. Adults with unilateral spastic CP spent less time in sedentary behavior and more time in MPA, VPA, MVPA and total activity than adults with bilateral CP. Data from adults with non-spastic forms of CP were excluded from analyses due to the small numbers of adults in this group ($n = 4$).

Overall, adults with CP spent more time in sedentary behavior ($p < 0.001$) and less time in LPA ($p < 0.001$), MPA ($p < 0.001$), VPA ($p < 0.01$), MVPA ($p < 0.001$), and total activity (mean counts·min^{-1}) ($p < 0.001$) than adults without CP (see Fig. 1). When analyzed according to GMFCS level, however, there was no difference in any physical activity outcome between adults in GMFCS level I and age- and sex-matched control participants. A trend towards a significant difference was observed for VPA ($p = 0.057$). Adults in level II spent more time in sedentary behavior ($p < 0.001$), and less time in LPA and total activity than control participants ($p < 0.01$). Time spent in MPA, VPA and MVPA did not differ between adults in GMFCS level II and control participants. Adults in level III spent more time in sedentary behavior and less time in LPA, MPA, VPA, MVPA, and total activity than control participants ($p < 0.01$ for all).

3.2. Adherence to physical activity guidelines among adults with and without CP

Ten adults with CP (24.4%) and 22 adults without CP (53.7%) met the ACSM guideline of 150 min of MVPA per week ($\chi^2 = 7.38$, $p < 0.01$). The number of adults meeting the guideline was significantly less across worsening gross motor function [GMFCS level I: $n = 7$ (53.8%); GMFCS level II: $n = 3$ (16.7%); GMFCS level III: $n = 0$ (0.0%); $\chi^2 = 9.92$, $p < 0.01$]. Adherence to the guideline for vigorous activity was not calculated because of the small quantity of VPA accumulated by adults with CP.

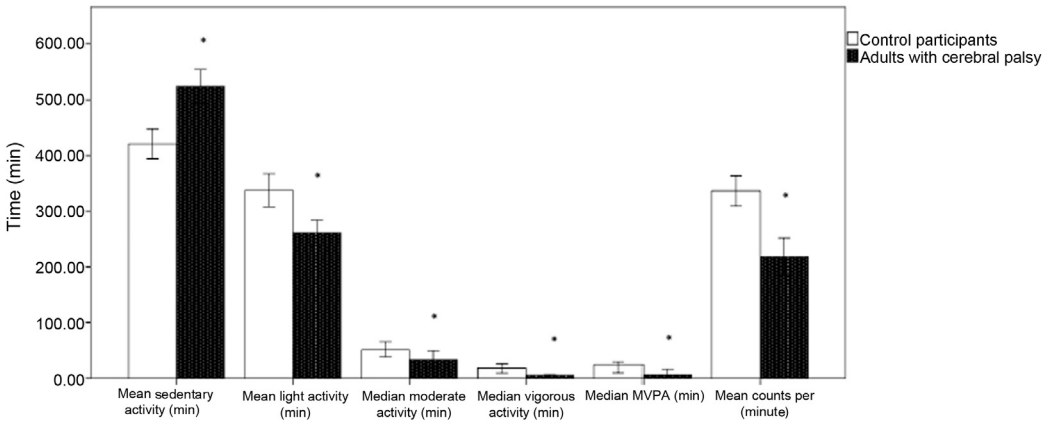

Fig. 1. Time spent in sedentary, light, moderate, vigorous and moderate-to-vigorous activity accumulated in 10 min bouts (MVPA), and mean counts per minute, per day among adults with and without cerebral palsy. Error bars represent 95% confidence intervals.

Table 3
Cardiometabolic risk factors among participants with cerebral palsy, presented across Gross Motor Function Classification System level.

	Total		GMFCS level I		GMFCS level II		GMFCS level III	
	M	SD	M	SD	M	SD	M	SD
BMI ($kg\,m^{-2}$)	24.5	3.6	24.7	3.8	24.4	3.0	24.2	4.5
WC (cm)	82.9	11.5	83.3	13.5	83.6	10.1	80.9	12.1
WHR	0.85	0.09	0.85	0.10	0.85	0.09	0.86	0.08
WHtR	0.51	0.07	0.49	0.07	0.51	0.06	0.52	0.07
Systolic BP (mm Hg)	126.6	13.9	127.2	17.2	127.1	14.6	125.0	7.6
Diastolic BP (mm Hg)	75.7	9.2	72.2	12.0	78.4	8.3	75.4	4.5
Total cholesterol ($mmol\,L^{-1}$)	4.63	0.88	4.38	0.92	4.89	0.93	4.49	0.68
HDL-cholesterol ($mmol\,L^{-1}$)	1.57	0.38	1.41	0.36	1.66	0.36	1.64	0.38
TC/HDL-C ratio	2.97	1.30	3.14	1.41	2.96	1.17	2.79	1.34
LDL-cholesterol ($mmol\,L^{-1}$)	2.66	0.76	2.54	0.84	2.84	0.71	2.50	0.74
Triglycerides[a] ($mmol\,L^{-1}$)	0.80	0.42	0.95	0.51	0.81	0.25	0.75	0.29
Plasma glucose[a] ($mg\,dL^{-1}$)	84.6	10.8	84.6	9.6	85.5	9.6	81.9	9.6
HOMA-IR	1.87	1.76	1.72	1.73	1.92	1.94	2.02	1.47
HbA_{1c} ($mmol\,mol^{-1}$)	32.0	2.8	31.2	1.8	32.1	3.5	32.9	2.6
25OH vitamin D ($nmol\,L^{-1}$)	43.1	1.7	40.1	1.5	43.0	1.9	47.5	1.5

[a] Variable not normally distributed, data presented as median (IQR).

3.3. Cardiometabolic risk factors in adults with CP

Two adults (5%) were taking antihypertensive medication. Three adults (7.3%) were taking cholesterol medication. One person reported a pre-diagnosis of type I diabetes mellitus. This person was removed from all analyses of blood biomarkers of glucose metabolism (i.e. plasma glucose, HOMA-IR, HbA_{1c}). A value for plasma glucose was missing for one person and the HbA_{1c} assay was missing for one person due to processing errors. Cardiometabolic risk factors across GMFCS level are presented in Table 3. The prevalence of overweight/obesity was 41.5%, the prevalence of central obesity was 36.6%, the prevalence of the metabolic syndrome was 20.5% and the prevalence of high risk CRP was 14.6%.

Regression models to show how physical activity components were associated with cardiometabolic risk factors are presented in Table 4. Regression analysis revealed that when age and sex were adjusted for MPA was associated with WHtR. When total activity was additionally controlled MPA remained associated with WHtR. Significant associations were also observed between MPA and WC, systolic blood pressure and diastolic blood pressure when adjusted for age, sex and total activity. Logistic regression analysis revealed that neither physical activity nor sedentary behavior was associated with the metabolic syndrome or high risk CRP.

4. Discussion

The results of the current study indicate that adults with CP spend more time in sedentary behavior and less time in light, moderate, vigorous and total physical activity than adults without CP. Although previous studies have similarly reported reduced levels of total activity among adults and children with CP (Maher, Williams, Olds, & Lane, 2007; Nieuwenhuijsen

Table 4
Multiple linear regression analyses to examine the contribution of moderate physical activity to cardiometabolic risk factors.

Dependent variable	R^2	Independent variables	Standardized beta	p-Value	F
Waist-height ratio	0.377	Age	0.509	0.000	7.455**
		Sex	0.381	0.008	
		Moderate physical activity	−0.314	0.026	
Waist-height ratio	0.400	Age	0.538	0.000	5.988**
		Sex	0.384	0.007	
		Mean counts·min^{-1}	0.269	0.250	
		Moderate physical activity	−0.538	0.028	
Waist circumference	0.575	Age	0.455	0.000	12.171**
		Sex	0.676	0.000	
		Mean counts·min^{-1}	0.386	0.054	
		Moderate physical activity	−0.518	0.012	
Systolic blood pressure	0.283	Age	0.308	0.047	2.756*
		Sex	0.375	0.023	
		Antihypertensive medication	0.073	0.474	
		Mean counts·min^{-1}	0.523	0.048	
		Moderate physical activity	−0.592	0.031	
Diastolic blood pressure	0.293	Age	0.427	0.007	2.897*
		Sex	0.045	0.777	
		Antihypertensive medication	0.154	0.322	
		Mean counts·min^{-1}	0.530	0.044	
		Moderate physical activity	−0.636	0.020	

* $p < 0.05$.
** $p < 0.01$.

et al., 2009) this is the first study to quantify the time that adults with CP spend in each component of physical activity. In addition, this is first study to demonstrate that a significantly smaller proportion of adults with CP meet physical activity guidelines compared to adults without CP. MPA was negatively associated with a number of cardiometabolic risk factors, suggesting that this population is at increased risk of developing chronic disease as a result of reduced levels of activity.

Similar to previous studies of adults and children with CP (Bjornson, Belza, Kartin, Logsdon, & McLaughlin, 2007; Nieuwenhuijsen et al., 2009), adults in level I accumulated comparable levels of physical activity to able-bodied adults. In fact they accumulated a mean of 27.4 min of MVPA per day, resulting in over half of these adults meeting the guideline. Adults in GMFCS level II, however, spent more time in sedentary behavior, and less time in LPA and total activity than adults without CP. Interestingly, they accumulated similar levels of MPA, VPA and MVPA as control participants. It is possible that adults with mild to moderate impairments participate in MVPA while attempting to keep up with their able-bodied peers during everyday life. The combination of trying to balance the activity involved in daily life and the greater energetic cost of locomotion associated with CP (Brehm, Becher, & Harlaar, 2007) may, however, result in an energy imbalance and chronic fatigue, a primary complaint among adults with CP (Van Der Slot et al., 2012). Adults in level II may therefore reduce light activity and increase sedentary behavior in an attempt to preserve energy. Despite achieving similar levels of MVPA as able-bodied participants, it should be noted that, of concern, only 16.7% of adults in GMFCS level II met the physical activity guideline.

As expected, adults in GMFCS level III participated in the least amount of physical activity; no adults in this group met the physical activity guideline. As well as accumulating little or no MVPA they spent a large proportion of the day in sedentary behavior. There is evidence in the general adult population that sedentary behavior is strongly associated with T2DM and cardiometabolic risk factors, independent of time in MVPA (Healy et al., 2011; Stamatakis, Hamer, Tilling, & Lawlor, 2012). In the current study however, sedentary behavior was not associated with any cardiometabolic risk factor. This may be because the relationship between objectively measured sedentary behavior and cardiometabolic risk factors is less consistent than that between self-reported sedentary behavior and risk factors (Stamatakis et al., 2012). Some research suggests that the type of sedentary behavior, in particular TV-viewing, rather than the volume of sedentary behavior is associated with cardiometabolic risk factors (Carson & Janssen, 2011; Stamatakis et al., 2012). This information was not captured by accelerometry in the current study.

Although no association was observed between sedentary behavior and cardiometabolic risk factors, MPA was negatively associated with a number of risk factors. This is in contrast to a recent study in Dutch adults with CP that was unable to find an association between physical activity and cardiovascular risk factors (van der Slot et al., 2013). This is likely because the association between individual components of physical activity and risk factors was not investigated.

The association between physical activity and risk factors may be mediated through the effect of excess adiposity on cardiometabolic disease. In the current study MPA was associated with measures of central adiposity but not BMI. Similarly, anthropometric measures of central obesity, but not BMI, are associated with cardiometabolic risk factors in adults with CP (Peterson, Haapala, & Hurvitz, 2012), probably because BMI is unable to identify excess adiposity in adults with impaired mobility (Peterson et al., 2013). Future studies investigating the effect of exercise interventions in adults with CP should

evaluate changes in abdominal adiposity, which can occur in the absence of changes in BMI even in the general population (Kay & Fiatarone Singh, 2006), and subsequent changes in cardiometabolic risk.

4.1. Limitations

There are a number of limitations to this study including the cross-sectional design, the inability to generalize the results to non-ambulatory adults with CP, and the lack of dietary assessment. The studied sample was also relatively small. There is currently no CP register in the Republic of Ireland and the majority of rehabilitative services are only provided up until age 18 years. International research reported that less than one-third of adults with CP are under the regular control of a rehabilitation physician (Hilberink et al., 2007). Despite every effort being made to recruit adults for this study the relatively low participation may have resulted in selection bias. In particular adults with an interest in preventive health and being physically active may have been more likely to participate. As information was not available on adults who did not respond to the study invite, comparisons cannot be made between responders and non-responders. The accelerometer used in this study was also not water-proof and therefore was unable to measure physical activity accumulated during water sports. Only 6 participants (14.6%) however, reported swimming for between 1 and 3 h per week.

5. Conclusion

The results of this study suggest that a large proportion of adults with CP do not meet physical activity guidelines. As well as spending less time in total physical activity adults with CP spent less time in MPA and VPA, and more time in sedentary behavior than their able-bodied peers. The negative association between MPA and cardiometabolic risk factors suggests that policy and intervention should be implemented to increase MPA in adults with CP in order to reduce cardiometabolic disease risk in this population.

Conflict of interest

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