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Reduced Moderate-to-Vigorous Physical Activity and Increased Sedentary Behavior Are Associated With Elevated Blood Pressure Values in Children With Cerebral Palsy

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Background. Children with cerebral palsy (CP) participate in reduced levels of physical activity and spend increased time in sedentary behavior. The effect of reduced activity and increased sedentary behavior on their cardiometabolic health has not been investigated.

Objectives. The purposes of this study were: (1) to investigate the prevalence of overweight/obesity and elevated blood pressure (BP) among a cohort of ambulatory children with CP and (2) to investigate the associations among physical activity, sedentary behavior, overweight/obesity, and BP in children with CP.

Study Design. This was a cross-sectional study of 90 ambulatory children, aged 6 to 17 years, with CP.

Methods. Body mass index (BMI), waist circumference, waist-height ratio, and BP were measured on 1 occasion. Habitual physical activity was measured by accelerometry over 7 days.

Results. The prevalence of overweight/obesity in the cohort was 18.9%. Twenty-two percent of the children had BP values within the hypertensive or prehypertensive range. Systolic BP was positively associated with waist circumference ($\beta = .324$, $P < .05$) and BMI ($\beta = .249$, $P < .05$). Elevated BP values were associated with reduced time in moderate-to-vigorous activity, vigorous activity, and total activity, as well as increased time in sedentary behavior. The strongest association was observed between elevated BP and vigorous activity alone (odds ratio = 0.61, 95% confidence interval = 0.37–0.99, $P < .05$).

Limitations. A convenience sample was recruited for this study, and it is possible that this limitation resulted in selection bias.

Conclusions. Despite the relatively low prevalence of overweight/obesity, a relatively high proportion of children with CP had elevated BP values. Reducing sedentary behavior and increasing habitual physical activity, particularly vigorous activity, should be primary aims of rehabilitation in order to reduce cardiometabolic disease risk in this population.



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Children with cerebral palsy (CP) participate in reduced levels of habitual physical activity and spend more time in sedentary activities (eg, sitting, lying down) compared with their peers with typical development (TD).¹⁻³ Physical inactivity and increased sedentary behavior are contributing to the growing epidemic of childhood obesity. The prevalence of obesity among children and adolescents with CP has significantly increased in recent years. In 2003 to 2004, the prevalence of obesity among US children with CP was 16.5%—an increase of 8.8% over the previous decade.⁴ In 2007, a prevalence of 18.2% was reported.⁵ Perhaps counterintuitively, the highest prevalence was observed among ambulatory children with minimal impairments. The prevalence of obesity among this group was 22.7%⁵—significantly higher than the prevalence of 16.9%

reported among children and adolescents with TD for the same time period.⁶

Interventions to prevent childhood overweight should aim to both increase physical activity and reduce sedentary behavior.^{7,8} Moderate-to-vigorous physical activity (MVPA), in particular, is needed to prevent weight gain in children.^{7,9} The motor impairments associated with CP, including muscle weakness, poor selective motor control, spasticity, and decreased balance, may prevent children with CP from accumulating adequate levels of habitual MVPA. Decreasing sedentary time, therefore, may be a more feasible method of preventing overweight in children with CP.

Childhood overweight/obesity is contributing to an increase in the prevalence of hypertension among

children with TD.¹⁰ Reports of the prevalence of hypertension in children and adolescents range from 3% to 5%.¹⁰⁻¹³ Elevated blood pressure (BP) in childhood is associated with the development of atherosclerosis, particularly when combined with childhood obesity.^{14,15} Children who retain high BP from childhood to adulthood are also more likely to have adult type II diabetes mellitus.¹⁶ Physical activity is a primary therapeutic intervention for the prevention and treatment of hypertension in childhood.¹⁷ Despite the potentially increased risk of developing hypertension among children and adolescents with CP as a result of inactivity and increased sedentary behavior, the prevalence of elevated BP in this population has not been reported.

The aims of this study were: (1) to investigate the prevalence of overweight/obesity and elevated BP among a cohort of ambulatory children with CP and (2) to investigate the association among physical activity, sedentary behavior, overweight/obesity, and BP in children with CP.

Method

Sample

Ambulatory children with CP, aged 6 to 17 years, classified in level I, II, or III of the Gross Motor Function Classification System (GMFCS),¹⁸ participated in this study. The GMFCS distinguishes among levels of motor function based on functional mobility and the need for assistive technology, particularly mobility aids. Children in level I of the GMFCS are able to walk indoors and outdoors without assistance and can perform gross motor skills such as running and jumping. Children in level III require a handheld mobility device when walking indoors and use wheeled mobility when traveling long distances.

The Bottom Line

What do we already know about this topic?

Children with cerebral palsy (CP) have low levels of physical activity and increased sedentary behavior compared with their peers with typical development, which may increase their risk of developing overweight/obesity and elevated blood pressure.

What new information does this study offer?

Despite a relatively low prevalence of overweight/obesity, the prevalence of elevated blood pressure was relatively high in this cohort of children with CP classified in level I, II, or III of the Gross Motor Function Classification System. Increased sedentary behavior and reduced moderate-to-vigorous, vigorous, and total physical activity were associated with elevated blood pressure.

If you're a patient or a caregiver, what might these findings mean for you?

Children with CP should be encouraged to participate in moderate-to-vigorous physical activity such as sports and to reduce sedentary behavior in order to prevent cardiometabolic disease in young adulthood. Communities need to develop organized sports programs that can and will accommodate children with motor disabilities.

Table 1. Participants' Physical Characteristics Across Gross Motor Classification System (GMFCS) Levels^a

GMFCS Level	n	zBMI	WC	WHtR	zSBP	zDBP
I						
Males	38 ^b	0.33 (1.20, -0.07 to 0.72)	66.8 (10.5, 63.3-70.2)	0.45 (0.06, 0.43 to 0.47)	-0.14 (1.23, -0.55 to 0.27)	0.98 (1.40, 0.51 to 1.45)
Females	19	0.43 (0.95, -0.02 to 0.89)	63.5 (10.2, 58.5 to 68.4)	0.44 (0.05, 0.43 to 0.48)	-0.82 (0.99, -1.30 to -0.34)	0.40 (1.38, -0.27 to 1.06)
All	57	0.36 (1.11, 0.07 to 0.66)	65.7 (10.4, 62.9 to 68.4)	0.44 (0.07, 0.37 to 0.61) ^c	-0.37 (1.19, -0.69 to -0.05)	0.78 (1.41, 0.40 to 1.16)
II						
Males	9	0.54 (1.35, -0.50 to 1.58)	61.4 (9.5, 54.1 to 68.8)	0.44 (0.06, 0.40 to 0.49)	-0.73 (0.82, -1.36 to -0.10)	0.74 (0.58, 0.29 to 1.18)
Females	5	-0.87 (0.99, -2.09 to 0.35)	54.5 (2.0, 52.0 to 57.0)	0.39 (0.03, 0.36 to 0.42)	-0.86 (1.41, -2.61 to 0.90)	0.74 (0.51, 0.11 to 1.38)
All	14	0.03 (1.38, -0.77 to 0.83)	59.0 (8.3, 54.2 to 63.8)	0.41 (0.06, 0.36 to 0.54) ^c	-0.78 (1.02, -1.36 to -0.19)	0.74 (0.53, 0.43 to 1.05)
III						
Males	10 ^c	0.31 (0.79, -0.26 to 0.87)	64.9 (8.2, 59.0 to 70.7)	0.45 (0.03, 0.43 to 0.47)	-0.73 (0.51, -1.12 to -0.34)	0.48 (0.57, 0.04 to 0.92)
Females	9 ^d	0.22 (1.04, -0.57 to 1.02)	60.6 (7.6, 53.6 to 67.6)	0.46 (0.03, 0.43 to 0.49)	-1.42 (0.86, -2.22 to -0.63)	0.89 (0.88, 0.07 to 1.70)
All	19	0.27 (0.89, -0.16 to 0.70)	63.1 (8.0, 59.0 to 67.2)	0.45 (0.03, 0.44 to 0.47)	-1.04 (0.75, -1.43 to 0.64)	0.66 (0.73, 0.27 to 1.04)

^a Data presented as mean (standard deviation, 95% confidence interval) unless stated otherwise. zBMI = z scores for BMI, WC = waist circumference (in centimeters), WHtR = waist-height ratio, zSBP = z scores for systolic blood pressure, zDBP = z scores for diastolic blood pressure.

^b 1 value missing from zSBP and zDBP.

^c 1 value missing from zSBP and zDBP.

^d 2 values missing from zSBP, zDBP, WC and WHtR.

^e Data with a skewed distribution, presented as median (interquartile range, minimum-maximum).

Children with a severe intellectual disability or having undergone surgery in the previous 6 months were excluded from the study. Physical therapists in 6 centers, from an organization that provides services to children with disabilities, identified eligible children and provided them and their guardians with information leaflets and study invitations. Thirty-five children agreed to participate. A further national center for the care of people with disabilities searched its register of clients for eligible children, resulting in the identification of 227 children. Information leaflets and study invitations were posted to these children and their guardians. Fifty-five children responded to the invitation (a 24.2% response rate) and agreed to participate in the study. Participants (n=90) were a median (interquartile range [IQR]) age of 10 (6.0) years and predominantly male (n=57). The majority of participants were classified in GMFCS level I (63.3%) (Tab. 1). There was no difference in age across GMFCS levels. Forty-eight children (53.3%) had unilateral spastic CP, 39 (43.3%) had bilateral spastic CP, and 3 (3.3%) had a nonspastic form of CP.

Measures

Body composition. Body composition was characterized by standing height, body mass, body mass index (BMI), waist circumference (WC), and waist-height ratio (WHtR). Standing height was measured in bare feet at the end of a gentle inspiration to the nearest 0.1 cm using a portable stadiometer (Invicta Plastics Ltd, Leicester, United Kingdom). Participants used a walking aid or stable surface to maintain an upright position if required. Participants also were encouraged to straighten their ankles, knees, and hips if required. Body mass was measured to the nearest 0.1 kg in bare feet and light clothing using an electronic platform scale (Seca 635) (Seca, Birmingham,

United Kingdom). If participants were unable to maintain standing balance on the scale, their weight was measured while they were seated, and the mass of the chair was subtracted from the final reading. Waist circumference was measured 2 times, to the nearest 0.1 cm, on bare skin, midway between the lower rib margin and the iliac crest at the end of gentle expiration. All measurements were taken by a single researcher (J.M.R.). Body mass index was expressed as standard deviation scores using the International Obesity Task Force (IOTF) growth charts.¹⁹ Overweight and obesity were defined according to IOTF criteria. Central obesity was defined as WHtR ≥ 0.50 .²⁰

Blood pressure. 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 (Omron Corp, Kyoto, Japan). The Omron 705-IT has been validated as an accurate device for BP measurement in children and adolescents.²¹ The appropriate size cuff was chosen based on mid-arm circumference and placed so that the lower edge was 3 cm above the elbow crease and the bladder was centered over the brachial artery. Participants rested in a seated position with their back supported and legs uncrossed for at least 5 minutes before 3 measurements were obtained at a 1- to 2-minute interval. The average of the last 2 measurements was used in data analysis. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were expressed as standard deviation scores (zSBP and zDBP, respectively).²² Children with SBP or DBP above the 98th percentile were classified as hypertensive, and children with SBP or DBP between the 91st and 98th percentiles were classified as prehypertensive.

Physical activity. Physical activity and sedentary activity were measured with the RT3 accelerometer (Stayhealthy Inc, Monrovia, California). 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-minute epochs.

Valid activity data was defined as having at least 4 days data of at least 10 hours wear time per day.²³ Sedentary activity was defined as <41 counts $\cdot\text{min}^{-1}$. Light activity (LPA) was defined as 41 to 950 counts $\cdot\text{min}^{-1}$. Moderate activity (MPA) was defined as 950 to 3,410 counts $\cdot\text{min}^{-1}$. Vigorous activity (VPA) was defined as $>3,410$ counts $\cdot\text{min}^{-1}$.²⁴ Data are presented as time spent in LPA, MPA, VPA, and MVPA accumulated in 1-minute bouts. Time spent in MVPA accumulated in 10-minute bouts also is presented. One minute of activity below the moderate activity count threshold was allowed for before the bout was considered to be ended. Percentage of time spent in sedentary activity (ie, minutes spent in sedentary activity/total wear time) and mean activity counts also are presented. Finally, the percentage of children meeting the guideline of 60 minutes of MVPA activity per day was calculated.

Data Analysis

The distribution of the data was checked for normality using the Kolmogorov-Smirnov test. Age, WC, WHtR, MPA, VPA, mean activity counts, MVPA (1-minute bouts) and MVPA (10-minute bouts) were non-normally distributed. Moderate phys-

ical activity, VPA, MVPA (1-minute bouts), MVPA (10-minute bouts), and activity counts (counts $\cdot\text{min}^{-1}$) were subsequently square root transformed. Means and standard deviations are presented for each continuous variable with a normal distribution. Medians and IQR are presented for continuous variables with a skewed distribution. Prevalence data are presented as percentages. One-way analysis of variance tests, with post hoc least significant difference tests, were used to determine differences in normally distributed continuous variables across GMFCS levels. Kruskal-Wallis 1-way analysis of variance tests, with post hoc Mann-Whitney *U* tests, were used to investigate differences across GMFCS levels for continuous variables with a skewed distribution. The Pearson chi-square test was used for comparison of prevalence rates across sex and GMFCS levels.

Spearman correlation coefficients were calculated to investigate the association between age and zBMI, WC, WHtR, zSBP, zDBP, and each physical activity component. Multiple regression analysis was used to investigate the association among SBP, DBP, markers of total and central adiposity, and physical activity outcomes controlling for age, sex, and GMFCS level. The sample size allowed for approximately 10 participants per 1 independent variable to predict the dependent variables and, therefore, was deemed adequate to perform the following regression analyses. First, separate multiple regression analyses were conducted with zSBP and zDBP as dependent variables and zBMI, WC, WHtR, percentage sedentary time, LPA, MPA, VPA, MVPA, MVPA (10-minute bouts), and activity counts (counts $\cdot\text{min}^{-1}$) as independent variables. Second, multiple regression analyses were conducted with zBMI, WC, and WHtR as dependent variable and percentage sedentary time, LPA, MPA,

Table 2.Physical Activity Outcomes Across Levels of the Gross Motor Function Classification System (GMFCS)^a

Activity Intensity	n	Sedentary (%)	Light (min)	Moderate (min)	Vigorous (min)	Moderate-to-Vigorous (min)	Moderate-to-Vigorous (10-min Bouts) (min)	Mean Activity Count (counts·min ⁻¹)
GMFCS level I	49	31.7 (12.2, 28.2 to 35.2)	410.4 (69.1, 390.5 to 430.2)	94.0 (4.8, 82.2 to 106.5)	7.5 (2.3, 5.3 to 10.2)	102.8 (5.8, 89.2 to 117.3)	37.2 (6.7, 28.6 to 46.8)	431.1 (15.7, 385.2 to 479.7)
GMFCS level II	9	37.2 (11.9, 28.0 to 46.3)	404.6 (69.4, 351.3 to 458.0)	63.4 (6.9, 35.3 to 99.6)	3.0 (4.0, 0.04 to 10.76)	68.0 (9.1, 35.1 to 111.7)	15.0 (10.1, 2.0 to 39.9)	321.6 (14.8, 181.2 to 862.6) ^b
GMFCS level III	15	42.3 (15.8, 33.5 to 51.0)	390.2 (110.3, 251.0 to 477.4) ^b	56.5 (9.2, 34.0 to 84.6)	2.2 (1.4, 0.7 to 4.7)	59.5 (9.8, 35.7 to 89.3)	13.4 (7.3, 4.7 to 26.6)	284.5 (24.0, 200.4 to 383.3)
P value		.022	.197	.005	.013	.005	.003	.006

^a Data presented as mean (standard deviation, 95% confidence interval) unless stated otherwise.^b Data with a skewed distribution; presented as median (interquartile range, minimum-maximum).

VPA, MVPA, MVPA (10-minute bouts), and activity counts (counts·min⁻¹) as independent variables. The following model was used: block 1: age, sex, GMFCS level (entered as 2 dummy indicator variables, where 1=GMFCS level I, 0=other, and 1=GMFCS level III, 0=other); block 2: independent variable. A single independent variable was entered into the model, one at a time, to avoid multicollinearity. Finally, logistic regression was used to examine the relationship between elevated BP and percentage sedentary time, LPA, MPA, VPA, MVPA, MVPA (10-minute bouts), and activity counts (counts·min⁻¹). The dependent variable was dichotomized as 1=BP values in the hypertensive or prehypertensive range and 0=BP values in the normotensive range. Age, sex, and GMFCS level (entered as 2 dummy indicator variables) were entered in block 1. Physical activity parameters were entered separately in block 2 to avoid multicollinearity. Statistical significance was set at $P<.05$. Analyses were performed using SPSS, version 19 (SPSS Inc, Chicago, Illinois).

Results

Blood pressure was not obtained from 4 children (1 child in GMFCS level I and 3 children in GMFCS level III) because of nonadherence to use

of the BP cuff. Waist circumference, and hence WHtR, was not obtained from 2 children (both in GMFCS level III). Table 1 presents participants' zBMI, WC, WHtR, zSBP, and zDBP.

Prevalence of Overweight/Obesity and Elevated BP

Fourteen children (15.5%) were classified as overweight. Three children (3.3%) were classified as obese. Six girls (18.2%) and 11 boys (19.3%) were classified as overweight/obese; there was no difference in overweight/obesity across sexes ($\chi^2=0.017$, $P=.896$). Eleven children (19.3%), 3 children (21.4%), and 3 children (15.8%) were classified as overweight/obese in GMFCS levels I, II, and III, respectively; there was no significant difference in the prevalence of overweight/obesity across GMFCS level ($\chi^2=1.84$, $P=.912$). Seventeen children (19.3%) were classified as centrally obese. Although the prevalence of central obesity was higher among boys than girls (21.1% and 16.7%, respectively) and higher among children in GMFCS level I compared with GMFCS levels II and III (22.8%, 21.4%, and 5.9%, respectively), the difference was not statistically significant. Nine children (10.5%) had BP values in the hypertensive range,

and 10 children (11.6%) had BP values in the prehypertensive range. All 9 children with hypertensive values and 6 of the children with prehypertensive values were in GMFCS level I. Among children classified as overweight/obese, 6 (35.2%) had prehypertensive or hypertensive values. Among children classified as centrally obese, 29.4% had prehypertensive or hypertensive values. Age was positively correlated with WC ($r=.625$, $P<.01$) and zDBP ($r=.261$, $P<.05$).

Physical Activity and Sedentary Behavior

Valid activity data was collected on 73 children. There was no difference in sex, age, GMFCS level, zBMI, WC, WHtR, zSBP, or zDBP between children with and without activity data. Participants wore the RT3 for a median (IQR) period of 7.0 (1.0) days and for a mean (SD) time of 761.0 (58.4) minutes per day. Approximately 75% of children met the guideline of 60 minutes of MVPA per day. This percentage declined across GMFCS levels from 88% to 55% to 47% in levels I, II, and III, respectively ($\chi^2=12.600$, $P<.01$). There was a significant difference in time spent in sedentary activity, MPA, VPA, MVPA, MVPA (10-minute bouts), and total activity (mean counts·min⁻¹) across GMFCS levels

(Tab. 2). Children in level I spent more time in MPA, VPA, MVPA, MVPA (10-minute bouts), and total activity and less time in sedentary activity than children in level III ($P < .01$ for all). Children in level I also spent more time in MVPA (10-minute bouts) than children in level II ($P < .05$). Age was positively correlated with sedentary activity ($r = .532$, $P < .01$) and negatively correlated with LPA ($r = -.266$, $P < .05$), MPA ($r = -.445$, $P < .01$), MVPA ($r = -.398$, $P < .01$), and activity counts ($\text{counts} \cdot \text{min}^{-1}$) ($r = -.422$, $P < .01$).

Relationship Between Overweight/Obesity and BP

When age, sex, and GMFCS were controlled for, zSBP, but not zDBP, was positively associated with zBMI ($\beta = 0.249$, $P < .05$; R^2 change = .059) and WC ($\beta = 0.324$, $P < .05$; R^2 change = .062). The Figure shows the relationship between zSBP and WC and between zSBP and zBMI.

Relationship Among Physical Activity, Sedentary Behavior, Overweight/Obesity, and BP

Linear regression revealed no association between zSBP, zDBP, and any physical activity outcome. Similarly, there was no association between any measure of body fat and any physical activity parameter. Logistic regression, however, revealed that the likelihood of hypertensive BP increased with decreased time in MVPA, VPA, and total activity, as well as with increased time in sedentary activity ($P < .05$ for all) (Tab. 3).

Discussion

The first aim of this study was to investigate the prevalence of overweight/obesity and elevated BP among a cohort of ambulatory children with CP. The prevalence of overweight/obesity in the current study was 18.9%. The prevalence of BP values in the hypertensive range was 10%. The second aim of this study was to investigate the associa-

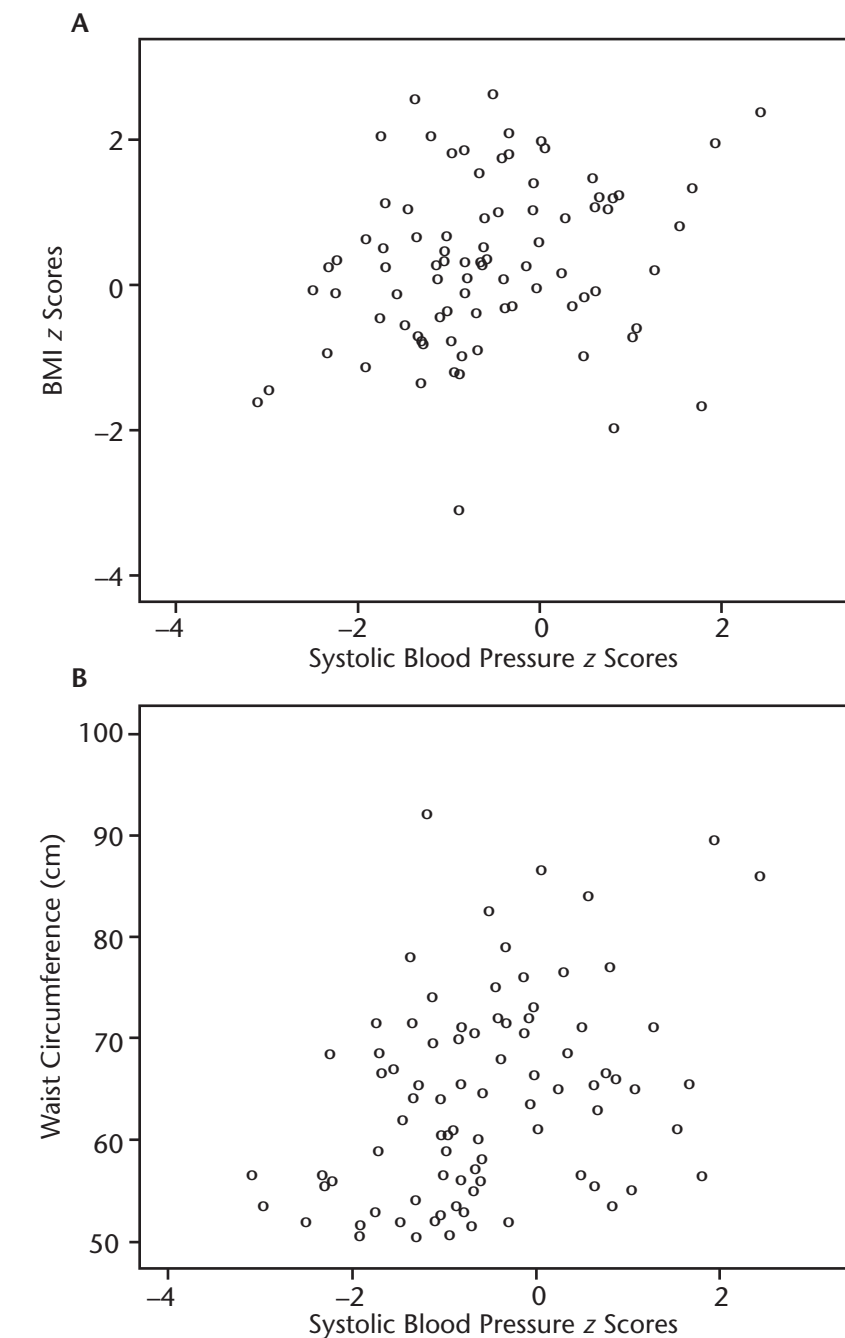


Figure.

Correlation between (A) body mass index (BMI) and systolic blood pressure and (B) waist circumference and systolic blood pressure.

tion among physical activity, sedentary activity, overweight/obesity, and BP in children with CP. This is the first study to demonstrate that anthropometric measures of total and central adiposity are positively associated with BP in children and

adolescents with CP. This finding is consistent with findings in children with TD.^{25,26} In addition, elevated BP in children and adolescents with CP is associated with decreased time spent in MVPA, VPA, and total activity, as well as with increased time

Table 3.Logistic Regression Analyses of the Association Between Blood Pressure Values in the Prehypertensive/Hypertensive Range and Physical Activity Outcomes^a

Independent Variable	β (SE)	Odds Ratio	95% CI	P	Nagelkerke Pseudo R ²
Sedentary activity	.064 (.032)	1.066	1.001 to 1.135	.047	.191
Light activity	-.001 (.004)	0.999	0.990 to 1.007	.739	.103
Moderate activity	-.389 (.198)	0.678	0.460 to 0.999	.050	.200
Vigorous activity	-.501 (.248)	0.606	0.372 to 0.986	.044	.199
Moderate-to-vigorous activity	-.356 (.179)	0.701	0.494 to 0.994	.046	.203
Moderate-to-vigorous activity (10-min bouts)	-.260 (.146)	0.771	0.579 to 1.026	.075	.177
Mean activity count (counts·min ⁻¹)	-.277 (.118)	0.758	0.602 to 0.955	.019	.247

^a The dependent variable in each model was participants with blood pressure values in prehypertensive/hypertensive range versus participants with blood pressure values in normotensive range. All analyses included age, sex, and Gross Motor Function Classification System level as independent variables. 95% CI=95% confidence interval.

spent in sedentary activity. Increasing physical activity and decreasing sedentary behavior, therefore, should be a primary aim of rehabilitation in order to prevent children with CP developing hypertension.

Prevalence of Overweight/Obesity and Elevated BP Values

In agreement with previous research,^{4,5} overweight/obesity was highest among children with minimal impairments (19.3% in GMFCS level I and 21.4% in GMFCS level II). The overall prevalence of overweight/obesity was lower than the prevalence reported among a cohort of US children with CP (29.1%)⁵ and lower than that reported among children with TD in the Republic of Ireland (23% and 28% for boys and girls, respectively).²⁷ A convenience sample was recruited for this study, and it is possible that participants were healthier than the general population of children with CP, as they had to volunteer to have their body composition and physical activity measured. This is the first study to demonstrate that central obesity, defined by WHtR, also was highest among children with minimal impairments (22.8% in GMFCS level I, 21.4% in

GMFCS level II, and 5.9% in GMFCS level III). The prevalence of elevated WC among adults with bilateral CP has been reported as 26%.²⁸ There are no comparative data for central obesity available among Irish children with TD or children with CP.

Despite the relatively low prevalence of overweight/obesity, a higher proportion of children with CP had elevated BP values compared with recent reports in children with TD (2.9% and 4.9% in US and Irish children and adolescents, respectively).^{11,13} A recent study showed that a number of cardiovascular risk factors were present in a sample of relatively young adults with CP, including hypertension (prevalence rate 26%).²⁸ This finding and the results of the current study suggest that people with CP may be at increased risk of developing cardiovascular disease and preventive strategies should be implemented in childhood.

Relationship Between Overweight/Obesity and BP

Similar to findings in children with TD,^{13,29} a significant proportion of children with overweight/obesity had elevated BP (35.2%). Although

this finding suggests that classification of weight status into normal weight and overweight/obese may be clinically useful for identifying children at increased risk of obesity hypertension, the prevalence of hypertension is known to increase across the entire range of BMI values.¹⁰ A simple threshold may not be adequate to define risk of hypertension among children. Furthermore, the results of this study indicate that BMI may not be the best anthropometric indicator of elevated BP in children with CP. A stronger association was observed between SBP and WC, compared with BMI. This finding is in agreement with recent findings that a measure of central adiposity (waist-hip ratio) was a better predictor of cardiometabolic risk in adults with CP.³⁰ Body mass index is a poor predictor of body fat in children with CP,³¹ possibly because it does not recognize that children with CP have reduced muscle volumes compared with age-matched able-bodied peers.³² Applying BMI cutoff points developed in the general population to children with CP may result in incorrect classification of children with excess body fat as normal weight.

Unlike BMI, WC provides an indicator of visceral adipose tissue, which is associated with increased cardiometabolic risk in children.^{33,34} Classifying obesity among children with CP according to WC thresholds may, therefore, provide a more accurate indicator of those at risk for cardiometabolic disease. The clinical utility of WC, however, is currently limited by the lack of consensus regarding what threshold should be used to classify central obesity in children. It has been suggested that WHtR ≥ 0.50 is a clinically useful threshold for identifying children of a normal weight who have increased cardiometabolic risk.²⁰ The results of this study and other studies,^{25,35} however, indicate that WHtR is not supe-

rior to WC or BMI at predicting BP in children with TD or children with CP.

Nonlinear Relationship Between Physical Activity and BP

Not unexpectedly, physical activity was not linearly related with SBP or DBP in the current study. Studies investigating the association between objectively measured physical activity and BP in children with TD have shown inconsistent results.³⁶⁻³⁸ This inconsistency is likely because the relationship between BP and physical activity appears to be nonlinear, with physical activity having a greater effect on BP in the high risk range.³⁸ This also appears to be the case in children and adolescents with CP. Of the physical activity parameters examined, vigorous activity had the strongest inverse association with elevated BP in children with CP. Recent research in children with TD supports this finding that VPA, but not MPA, is associated with lower cardiometabolic risk.^{39,40}

It is possible that VPA is acting on BP through its effect on body fat. Unlike the current study, other studies of children with TD have shown an association between VPA and body fat, above that of MPA.^{7,39} It is likely that this association was not observed in the current study because of the small number of children with overweight/obesity who had valid activity data ($n=12$) and the heterogeneity of the sample in terms of age, sex, and GMFCS level. As a result of the relatively small sample size, the variation associated with these factors may have masked the association between physical activity and obesity. It also is possible that the measurements taken in this study did not provide a sensitive enough indication of body fat. Future research should investigate the association between body fat, as measured by a criterion standard such as dual-energy x-ray absorpti-

ometry, and physical activity in children with CP.

Physical Activity Among Children with CP

Although a seemingly high proportion of children (75%) met the guideline of 60 minutes of MVPA per day, 90% of adolescents with TD met the guideline when physical activity was measured by the same method.⁴¹ It has been suggested that the guideline of 60 minutes of MVPA per day should be in addition to the MVPA accumulated during activities of daily living to account for the fact that even the most sedentary children spend 30 to 40 minutes in MVPA, when measured with accelerometry, and that children who accumulate less than 90 minutes of MVPA have increased clustered cardiovascular risk.³⁶ Of concern is the fact that children in levels II and III accumulated only 68 and 60 minutes, respectively, of MVPA per day. Despite this, the prevalence of hypertension was higher among children in level I who accumulated more MVPA. This finding is difficult to explain. It may be because the smaller proportion of participants in levels II and III, compared with level I, resulted in a biased sample. It also is possible that using a single set of cutoff points to classify physical activity intensity among all children with CP resulted in an underestimation of physical activity intensity among children in level III, who use significantly more energy to walk at a given speed compared with children in levels I and II.⁴² Development of specific cutoff points according to GMFCS level may improve physical activity classification in this population.

Implications for Policy and Clinical Practice

Although there is not currently a guideline for VPA, this study, as well as other studies in children with TD,^{39,40} has identified the need to

emphasize participation in VPA. This finding has significant implications for exercise promotion and prescription among children with CP. Vigorous activity includes activities, such as running, jumping, and skipping, that children generally accumulate during participation in sports. Even children with CP who have minimal impairments participate less in organized sports than their peers with TD.⁴³ A number of personal and environmental factors act as barriers to participation in sports⁴⁴ and need to be addressed in order to increase everyday levels of VPA in this population.

Limitations

A number of limitations to this study, such as selection bias and use of a single cutoff point to classify physical activity intensity among children in all GMFCS levels, have been identified. In addition, although this study found a high prevalence of children with BP values in the hypertensive range, it cannot be diagnosed as hypertension without elevated readings on at least 3 occasions. The presence of elevated BP is known to decrease between the first and third readings¹⁰; however, a comparable study in Irish children with TD, which also took only 1 BP measurement, demonstrated a significantly lower prevalence of elevated BP (4.9%) despite more children being classified as overweight/obese (28%).¹³ It also is possible that measuring standing height in children with CP, particularly in GMFCS level III, may result in an underestimation of stature because of limitations in hip, knee, and ankle range of motion; however, the majority of children in this study had minimal impairments, which did not greatly affect the measurement of standing height.

In conclusion, total and central adiposity are associated with SBP in children with CP. Although decreased

time in total physical activity and MVPA and increased time in sedentary activity are associated with elevated BP in children with CP, the strongest association was observed for VPA alone. This finding has significant implications for exercise prescription in children with CP and suggests that health care professionals should be promoting participation in vigorous activities, such as sports, rather than participation in moderate activities, such as play, in this population.

Dr Ryan conceptualized and designed the study, carried out data collection, carried out data analysis, drafted the initial manuscript, and approved the final manuscript. Dr Hensey, Ms McLoughlin, and Mr Lyons contributed to the design of the study, provided study participants, reviewed and revised the manuscript, and approved the final manuscript as submitted. Dr Gormley conceptualized and designed the study, provided fund procurement, reviewed and revised the manuscript, and approved the final manuscript as submitted. The authors acknowledge all of the participating children and their parents for their cooperation in this study. They also thank the physical therapists in the Central Remedial Clinic and Enable Ireland for their support with the study.

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