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ORIGINAL ARTICLE

# Waist Circumference Provides an Indication of Numerous Cardiometabolic Risk Factors in Adults With Cerebral Palsy

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**Abstract**

**Objective:** To report the prevalence of cardiometabolic risk factors in a cohort of adults with cerebral palsy (CP) and to investigate the ability of anthropometric measures to predict these factors.

**Design:** Cross-sectional study.

**Setting:** Testing took place in a laboratory setting.

**Participants:** Adults with CP (N=55; mean age, 37.5±13.3y; Gross Motor Function Classification System levels, I–V) participated in this study.

**Interventions:** Not applicable.

**Main Outcome Measures:** Total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, triglycerides, glucose, insulin, and C-reactive protein levels were measured from a fasting venous blood sample. Insulin resistance was calculated using the Homeostasis Model Assessment (HOMA-IR) index. Blood pressure, body mass index (BMI), waist circumference (WC), waist-hip ratio, and waist-height ratio were also measured. The metabolic syndrome (MetS) was defined according to the 2009 Joint Interim Statement.

**Results:** The prevalence of the MetS was 20.5% in ambulatory adults and 28.6% in nonambulatory adults. BMI was associated with HOMA-IR only ($\beta=.451$; $P<.01$). WC was associated with HOMA-IR ($\beta=.480$; $P<.01$), triglycerides ($\beta=.450$; $P<.01$), and systolic blood pressure ($\beta=.352$; $P<.05$). Receiver operating characteristic curve analysis revealed that WC provided the best indication of hypertensive blood pressure, dyslipidemia, HOMA-IR, and the presence of multiple risk factors (area under the curve, .713–.763).

**Conclusions:** A high prevalence of the MetS was observed in this relatively young sample of adults with CP. WC was a better indicator of a number of risk factors than was BMI and presents as a clinically useful method of screening for cardiometabolic risk among adults with CP.

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Although cerebral palsy (CP) is a nonprogressive disorder, it is well reported that adults with CP develop secondary conditions with age including pain, stiffness, and poor balance.[1,2] These conditions contribute to a decline in physical functioning,[1] loss of mobility,[1] and physical inactivity[3] from early adulthood. Inactivity in typically developing adults is associated with an increased risk of developing type 2 diabetes mellitus, the metabolic syndrome (MetS), and a number of individual cardiometabolic risk factors.[4,5] If similar associations exist in adults with CP, they may be at an increased risk of developing cardiovascular disease and type 2 diabetes mellitus. Indeed, a 2- to 3-fold greater mortality rate as a result of coronary heart disease was reported among adults with CP compared to adults without CP.[6] In addition, a recent study reported that a number of cardiovascular risk factors were present among a sample of relatively young adults with CP, the mean age being 36.6 years.[7] Despite this evidence, there are currently no national screening programs that monitor cardiometabolic risk in persons with CP. Screening and preventive programs are a vital component of reducing the prevalence of cardiovascular disease and type 2 diabetes mellitus worldwide, which should be implemented before the process of atherosclerosis has progressed to an advanced stage.

Obesity is an independent risk factor for cardiovascular disease mortality.[8,9] The relationship between obesity and cardiovascular

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disease is mediated through the negative effect of excess visceral adiposity on risk factors such as blood pressure, blood lipids, insulin resistance, plasma glucose, and inflammatory markers.[10] Accurate screening of obesity in adults with CP is an important step toward identifying those with an increased risk of cardiovascular disease. Although body mass index (BMI) is historically used to classify obesity, a significant limitation of BMI is its inability to differentiate between an elevated body fat content and increased muscle mass. Normal-weight obesity (ie, people who have a normal weight based on BMI cutoff points but a high body fat content) is strongly associated with cardiometabolic dysregulation, a high prevalence of the MetS, and an increased risk of cardiovascular disease mortality.[8] The ability of BMI cutoff points to identify cardiometabolic risk may be particularly compromised in adults with CP, a population known to have reduced muscle mass.[11]

Using a criterion standard measure of body fat, such as magnetic resonance imaging, abdominal computed tomography, and dual-energy X-ray absorptiometry, is not always feasible in a clinical setting. Simple anthropometric measures such as waist circumference (WC), waist-hip ratio (WHR), and waist-height ratio (WHtR) have therefore been adopted as indicators of abdominal adiposity in the general population. Not only are these measures quick and easy to use, but research suggests that they are superior tools, in comparison to BMI, for identifying cardiometabolic risk.[12,13] This may be true because they provide an indicator of visceral adipose tissue, which is strongly associated with cardiometabolic risk factors and type 2 diabetes mellitus.[14] Only 1 study has specifically investigated the ability of anthropometric measures to predict cardiometabolic risk in adults with CP.[15] In this study, WHR was found to be a significant predictor of high-density lipoprotein cholesterol (HDL-C), total cholesterol (TC)/HDL-C ratio, and triglycerides. The association between anthropometric measures and other cardiometabolic risk factors, however, in particular blood pressure, insulin resistance, glucose, and inflammatory markers, has not been investigated in adults with CP. The purpose of this study was to report the prevalence of cardiometabolic risk factors in a cohort of adults with CP and to investigate the ability of simple indicators of adiposity to predict these factors.

## Methods

Fifty-five adults with CP, in levels I to V of the Gross Motor Function Classification System (GMFCS) (31 men and 24 women; mean age, 37.5±13.3y; range, 18–65y), were recruited from the Central Remedial Clinic, a national center for the treatment and care of people with disabilities, and through general practitioners nationwide. The GMFCS is a 5-point scale that distinguishes between levels (I–V) of motor function on the basis of functional mobility and the need for assistive technology, particularly mobility aids.[16] Adults with a severe intellectual disability (intelligence quotient <35) and pregnant women were excluded from participating in this study.

The register of the center was searched for eligible persons, resulting in study invitations being sent to 263 adults with CP. Forty-three adults with CP responded and consented to participate. Information about the study and a request to recruit eligible persons was sent to 1367 general practitioners; 7 participants were recruited by this method. The remaining participants were recruited by word of mouth. Ethical approval for this study was granted by the Faculty of Health Sciences' ethics committee and the Central Remedial Clinic's ethics committee. All participants, and their guardians in the case of adults with mild-to-moderate intellectual disability, provided written informed consent before data collection.

***List of abbreviations:***

| | |
|---|---|
| **BMI** | **body mass index** |
| **CP** | **cerebral palsy** |
| **CRP** | **C-reactive protein** |
| **GMFCS** | **Gross Motor Function Classification System** |
| **HDL-C** | **high-density lipoprotein cholesterol** |
| **HOMA-IR** | **Homeostasis Model Assessment of insulin resistance** |
| **LDL-C** | **low-density lipoprotein cholesterol** |
| **MetS** | **metabolic syndrome** |
| **ROC** | **receiver operating characteristic** |
| **TC** | **total cholesterol** |
| **WC** | **waist circumference** |
| **WHR** | **waist-hip ratio** |
| **WHtR** | **waist-height ratio** |

## Measurements

### Anthropometric measures

Anthropometric measures including stature, body mass, WC, and hip circumference were obtained. In the case of nonambulatory participants, stature was predicted from knee height.[17] Knee height was measured with the knee and ankle held at 90°, from the posterior surface of the thigh, just proximal to the patella, to the sole of the foot, using calipers. WC was measured, on bare skin, to the nearest 0.1cm midway between the lower rib margin and the iliac crest at the end of gentle expiration. Hip circumference was measured to the nearest 0.1cm at the end of gentle expiration around the maximum circumference of the buttocks. WC and hip circumference were measured on ambulatory participants in standing and on nonambulatory participants in supine lying positions. The mean of 2 measurements was calculated for both WC and hip circumference. Overweight and obesity were defined as BMI $\geq$25kg/m$^2$ and $\geq$30kg/m$^2$, respectively. Central obesity was defined as WC $\geq$80cm and $\geq$94cm for women and men, respectively.[18]

### Cardiometabolic risk factors

Blood pressure was measured from the right arm or the least affected side, in the case of significant asymmetry, using the Omron 705 IT blood pressure monitor.[a] The Omron 705 IT has demonstrated excellent validity in adults.[19] Participants rested in a seated position with their backs supported for at least 5 minutes before 3 measurements were taken at 1- to 2-minute intervals. The average of the last 2 measurements was used in data analysis. Hypertensive blood pressure was defined as systolic blood pressure $\geq$140mmHg or diastolic blood pressure $\geq$90mmHg.[20] People who reported taking any hypertension-lowering medication were automatically classified as hypertensive.

Blood was drawn following an overnight fast (10h) and processed according to standard procedures in the Biochemistry Department, St James's Hospital, Dublin. Insulin level was measured by using the electrochemiluminescence immunoassay (Elecsys Insulin Assay[b]). Enzymatic, colorimetric assays (Roche/Hitachi cobas c systems[b]) were used to measure fasting glucose, TC, HDL-C, and triglyceride levels. Low-density lipoprotein cholesterol (LDL-C) level was calculated using the Friedewald equation.[21] High-sensitivity C-reactive protein (CRP) level was measured by using particle-enhanced immunoturbidimetric assay

(Roche/Hitachi cobas c systems). TC/HDL-C ratio was also calculated.

The MetS was defined according to the most recent Joint Interim Statement.[18] To evaluate insulin resistance, the Homeostasis Model Assessment (HOMA-IR) index[22] was used. Insulin resistance was defined by the 75th percentile of the HOMA-IR index of the participants being studied (HOMA-IR index = 2.51).[23] The presence of elevated levels of TC, LDL-C, triglycerides, and low HDL-C was defined according to the National Cholesterol Education Program, Adult Treatment Panel III.[24] The following cutoffs were applied: hypercholesterolemia ≥5.2 mmol/L, high LDL-C ≥3.4mmol/L, hypertriglyceridemia ≥1.7mmol/L, and low HDL-C <1.0mmol/L. People who reported taking any cholesterol medication were automatically classified as having abnormal TC, TC/HDL-C ratio, HDL-C, and LDL-C. Fasting glucose was categorized according to the cutoff point identified by the Joint Interim Statement on the MetS (hyperglycemia ≥100mg/dL).[18] High-risk CRP was categorized as >0.3mg/dL.[25]

## Statistical analysis

The distribution of the data was checked for normality by using the Kolmogorov-Smirnov test. The logarithm function was applied to TC/HDL-C ratio and HOMA-IR index to transform these data to a normal distribution. Means and SDs were computed for each of the normally distributed continuous variables. Medians and interquartile ranges were computed for skewed data. Prevalence data are presented as percentages. Differences between continuous variables with a normal distribution were determined by using independent *t* tests. Differences between continuous variables with a skewed distribution were determined by using Mann-Whitney *U* tests. Pearson's chi-square test was used for comparison of independent groups of categorical data. Pearson's partial correlation test (controlled for gender) was used to examine correlations between GMFCS level and each anthropometric measure.

To determine the association between cardiometabolic outcomes (ie, systolic blood pressure, diastolic blood pressure, TC, HDL-C, TC/HDL-C ratio, LDL-C, triglycerides, glucose, HOMA-IR index, CRP) and anthropometric measures (BMI, WC, WHR, WHtR), separate multiple regression analyses were conducted for each dependent variable (ie, cardiometabolic outcome). Age, gender, and ambulatory status, defined as 1 = GMFCS levels I to III and 0 = GMFCS levels IV to V, were adjusted for in each analysis. The following model was used for all analyses: block 1: age, gender, ambulatory status; block 2: anthropometric measure. Each anthropometric measure was entered in a separate analysis to avoid multicollinearity. When systolic blood pressure or diastolic blood pressure was the dependent variable of interest, the analysis was additionally adjusted for self-reported taking of antihypertensive 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, additional adjustment was made for self-reported taking of cholesterol medication (coded as 1 if yes or 0 if no). To examine whether WC, WHR, or WHtR were associated with cardiometabolic risk factors independent of BMI, follow-up analyses were conducted between each cardiometabolic risk factor and WC, WHtR, and WHR, additionally adjusting for BMI in block 1. Variance inflation factors <5 revealed no issue with collinearity.

A receiver operating characteristic (ROC) curve analysis was conducted to compare the anthropometric measures at predicting the presence of individual cardiometabolic risk factors (hypertensive blood pressure, hypercholesterolemia, low HDL-C, high LDL-C, hypertriglyceridemia, hyperglycemia, high HOMA-IR index, high-risk CRP) and the presence of ≥2 risk factors. An area under the ROC curve of >.90 is considered excellent; .80 to .90 is considered good; and .70 to .80 is considered fair. All analyses were performed using Analyse-it for Microsoft Excel (version 2.20)[c] and IBM SPSS Statistics (version 19).[d] Statistical significance was set at $P<.05$.

# Results

The demographic and diagnostic distribution of participants is presented in table 1. A value for CRP and insulin was missing for 1 nonambulatory person and a value for plasma glucose was missing for 1 ambulatory person, as a result of processing errors. One ambulatory person reported a prediagnosis of type 1 diabetes mellitus. This person was removed from all analyses of blood biomarkers of glucose metabolism (ie, plasma glucose, insulin, HOMA-IR index) and the MetS. Hip circumference was not obtained from 2 nonambulatory adults because of significant contractures. Participants' anthropometric measures and cardiometabolic outcomes are presented in table 1. Within the study cohort, BMI ranged from 12.3 to 36.8kg/m$^2$, WC ranged from 64 to 126.5cm, WHR ranged from 0.68 to 1.11, and WHtR ranged from .36 to .81. Four participants (7.3%) were obese according to BMI cutoffs. The prevalence of central obesity was 36.4% (table 2). A significant difference between ambulatory and nonambulatory adults was observed for WHR ($P<.05$), HDL-C ($P<.01$), and TC/HDL-C ratio ($P<.05$). There were no other between-group differences. Pearson's partial correlations revealed that the GMFCS was associated with hip circumference ($r=-.356$; $P<.05$) and WHR ($r=.287$; $P<.05$) when adjusted for gender.

Five adults (9.1%) were on antihypertensive medication. Five adults (9.1%) were taking cholesterol medication. Only 1 person reported smoking (<20 cigarettes per day). The prevalence of the MetS in the total cohort was 22.6% (see table 2).

The significant associations between anthropometric measures and cardiometabolic outcomes are presented in table 3. After adjusting for age, gender, and ambulatory status, WC, WHR, and WHtR were associated with the HOMA-IR index and triglyceride levels. WC was also associated with systolic blood pressure. BMI was associated with the HOMA-IR index only. WC and WHtR remained associated with triglyceride levels when the model was additionally adjusted for BMI. WC was also associated with systolic blood pressure independent of BMI. The ability of BMI, WC, WHR, and WHtR to predict the presence of cardiometabolic risk factors, as determined by area under the curve values, is presented in table 4. ROC curve analysis was not performed on fasting glucose because of the small number of people defined as having elevated fasting glucose (n = 3). The area under the curve for hypertensive blood pressure, hypercholesterolemia, high HOMA-IR index, high LDL-C, and the presence of ≥2 risk factors was highest for WC (.643−.750). Area under the curve values for low HDL-C and high triglycerides were highest for WHtR (.711 and .900, respectively).

# Discussion

The aims of this study were to report the prevalence of cardiometabolic risk factors in adults with CP and to investigate their association with anthropometric measures. The prevalence of the MetS in this relatively young cohort of adults with CP was 22.6%.

**Table 1** Participants' characteristics, anthropometric measures, and cardiometabolic outcomes by ambulatory status

| Characteristic | Total (n=55) | Ambulatory (n=41) | Nonambulatory (n=14) |
|---|---|---|---|
| Males, females | 31, 24 | 19, 22 | 12, 2 |
| Age (y) | 37.5±13.3 | 36.5±12.5 | 40.3±15.7 |
| Age (y), range | 18–65 | 18–62 | 18–65 |
| Spastic CP, n (%) | 49 (89.1) | 37 (90.2) | 12 (85.7) |
| Unilateral spastic | 15 (30.6) | 15 (40.5) | NA |
| Bilateral spastic | 34 (69.4) | 22 (59.5) | 12 (100.0) |
| Other,* n (%) | 6 (10.9) | 4 (9.8) | 2 (14.3) |
| GMFCS, n (%) | | | |
| I | 13 (23.6) | 13 (31.7) | NA |
| II | 18 (32.7) | 18 (43.9) | NA |
| III | 10 (18.2) | 10 (24.4) | NA |
| IV | 8 (14.5) | NA | 8 (57.1) |
| V | 6 (10.9) | NA | 6 (42.9) |
| Height (cm) | 163.3±10.0 | 163.9±10.9 | 161.7±7.0 |
| Weight (kg) | 64.9±14.0 | 65.9±13.1 | 61.9±16.5 |
| BMI (kg/m$^2$) | 24.2±4.4 | 24.5±3.6 | 23.6±6.2 |
| WC (cm) | 83.5±13.4 | 82.9±11.5 | 85.4±18.1 |
| WHR | 0.87±0.09 | 0.85±0.09† | 0.92±0.10† |
| WHtR | 0.51±0.08 | 0.51±0.07 | 0.53±0.11 |
| Systolic blood pressure (mmHg) | 126.2±14.3 | 126.6±13.9 | 125.1±15.8 |
| Diastolic blood pressure (mmHg) | 76.0±9.8 | 75.7±9.2 | 76.6±11.9 |
| TC (mmol/L) | 4.5±0.9 | 4.6±0.9 | 4.2±0.9 |
| HDL-C (mmol/L) | 1.48±0.39 | 1.57±0.38‡ | 1.21±0.29‡ |
| TC/HDL-C | 3.1±1.3 | 3.0±1.3† | 3.5±1.3† |
| LDL-C (mmol/L) | 2.64±0.77 | 2.66±0.76 | 2.56±0.82 |
| Triglyceride§ (mmol/L) | 0.8±0.5 | 0.8±0.4 | 0.8±1.1 |
| Plasma glucose§ (mg/dL) | 84.6±10.8 | 84.6±10.8 | 84.6±10.8 |
| HOMA-IR index (mU/L) | 1.75±1.74 | 1.87±1.76 | 1.44±1.62 |

NOTE. Values are mean ± SD or as otherwise indicated.
Abbreviations: IQR, interquartile range; NA, not applicable.
* Dyskinetic and ataxic CP were combined to form 1 group because of the small number of participants with these diagnoses.
† Between-group difference at $P<.05$.
‡ Between-group difference at $P<.01$.
§ Variables with a skewed distribution. Values are median ± IQR.

The prevalence of the MetS in ambulatory adults with CP was similar to that reported in a population of Irish adults aged 50 to 69 years (21%)[26] and American adults aged ≥20 years (21.8%).[27] In nonambulatory adults, the prevalence of 28.6% was, however, significantly higher than prevalence rates in the general population. A number of individual risk factors for cardiometabolic disease were also present in the cohort. Notably, although 15 participants (27.3%) had elevated LDL-C levels, only 5 participants were on medication for dyslipidemia. Screening for cardiometabolic risk factors should occur in this population from young adulthood to implement timely preventive programs. Regardless of age, gender, and ambulatory status, WC was associated with a number of cardiometabolic risk factors and may be used as a quick and easy method of identifying adults with CP at risk of developing cardiovascular disease and type 2 diabetes mellitus.

A recent study investigated the prevalence of cardiovascular disease risk factors in a sample of Dutch adults with CP (mean age, 36.6y; age range, 25–45y).[7] Although the prevalence of hypertensive blood pressure values in the Dutch cohort was higher (25.6%) than that in the current study, the prevalence of elevated TC, elevated fasting glucose, and low HDL-C levels was lower (7.0%, 0.0%, and 11.6%, respectively) than that in the present study. This may be because the Dutch cohort was less severely impaired compared with the current sample (only 2 adults were nonambulatory) and the relatively younger age range of participants.

The prevalence of obesity, defined by BMI, in the present study (7.3%) was relatively low in comparison to a sample of Dutch adults with CP (18.5%)[7] and to the general Irish adult population without CP (25%).[28] The use of BMI as an indicator of cardiovascular disease risk in adults with CP has been debated, however, given that it is unable to distinguish between body fat and muscle mass. Adults with CP experience significant muscle atrophy,[11] which may result in misclassification of overweight as normal weight if BMI cutoff points for the general population are used to classify overweight/obesity in adults with CP. Previous studies investigating the association between BMI and cardiometabolic risk factors in adults with CP have reported conflicting results. One study reported that BMI was associated with diastolic blood pressure and that there was a trend toward an association with 10-year risk of fatal cardiovascular disease.[7] A second study reported that BMI was not associated with TC, HDL-C, LDL-C, TC/HDL-C ratio, or triglycerides.[15] This is in agreement with the results of the present study. The present study is the first, however, to

**Table 2** Prevalence of overweight/obesity, cardiometabolic risk factors, and the MetS among participants

| Risk Factor | Total (n=55) | Ambulatory (n=41) | Nonambulatory (n=14) |
|---|---|---|---|
| BMI ≥25kg/m$^2$ | 18 (32.7) | 14 (34.1) | 4 (28.6) |
| BMI ≥30kg/m$^2$ | 4 (7.3) | 3 (7.3) | 1 (7.1) |
| Central obesity* | 20 (36.4) | 15 (36.6) | 5 (35.7) |
| Hypertensive blood pressure† | 11 (20.0) | 7 (17.1) | 4 (28.6) |
| Hypercholesterolemia‡ | 17 (30.9) | 13 (31.7) | 4 (28.6) |
| Low HDL-C‡ | 9 (16.4) | 4 (9.8) | 5 (35.7) |
| High LDL-C‡ | 15 (27.3) | 11 (26.8) | 4 (28.6) |
| Hypertriglyceridemia | 7 (12.7) | 4 (9.8) | 3 (21.4) |
| Hyperglycemia | 3 (5.7) | 3 (7.7) | 0 (0.0) |
| High-risk CRP | 9 (16.4) | 6 (14.6) | 3 (21.4) |
| MetS | 12 (22.6) | 8 (20.5) | 4 (28.6) |

NOTE. Values are n (%).

* Defined as waist circumference ≥80cm for women or ≥94cm for men.

† Including participants on antihypertensive medication.

‡ Including people on cholesterol medication.

investigate and demonstrate an association between BMI and insulin resistance in adults with CP.

Although the results of this study suggest that all anthropometric measures are associated with ≥1 cardiometabolic risk factors in adults with CP, ROC curve analysis indicated that WC was the best predictor of a number of cardiometabolic risk factors. This is in agreement with studies of the general population.[12,13] WC was also associated with triglyceride levels and systolic blood pressure independent of BMI. Unlike BMI, WC provides an indication of visceral adipose tissue. The secretion of proinflammatory cytokines and adipokines from visceral adipose tissue contributes to insulin resistance, hypertension, and dyslipidemia and may provide the link between central obesity and cardiovascular disease.[29] Imaging techniques such as magnetic resonance imaging, abdominal computed tomography, and dual-energy X-ray absorptiometry provide accurate measurements of visceral adipose tissue but are expensive and often unfeasible to use in the clinical setting. The consistent association between WC and cardiometabolic risk factors in this study suggests that WC provides a proxy measure of visceral adipose tissue among adults with CP and can be used to identify those at risk of developing cardiovascular disease and type 2 diabetes mellitus. Defining obesity according to WC, rather than BMI, may therefore be a more appropriate method of classifying obesity in adults with CP. Thresholds of 80cm for women and 94cm for men have been proposed for classifying abdominal obesity in able-bodied adults of European origin.[18] Further research is required, however, to validate these thresholds in adults with CP.

In agreement with previous research,[15] WHR was associated with a number of cardiometabolic risk factors. The relative predictive power of WHR, however, was not as high as that of WC. The predictive power of WHR in adults with CP may be influenced by its association with gross motor function. This association was a result of the inverse relationship between hip circumference and GMFCS level—an expected relationship considering the positive correlation between hip circumference, gluteal muscle, and total leg muscle mass.[30] Although some amount of muscle atrophy is present in all adults with CP, gluteal and total leg muscle mass particularly atrophy in nonambulatory adults.[31] As well as being associated with gross motor function, WHR is more difficult to assess and a less reliable measure than WC in the general population.[32] Difficulty with obtaining hip circumference measurements from nonambulatory participants or participants with significant contractures may also increase the potential for error when measuring WHR in adults with CP. In contrast, WC is a simple and feasible measure to take on ambulatory and nonambulatory adults in a clinical setting.

## Study limitations

This study has a number of limitations. Primarily, the cross-sectional design of the study does not allow causality to be inferred. In addition, the studied sample was relatively small and may have influenced the estimate of cardiometabolic risk. There is currently no CP register in the Republic of Ireland, and the majority of rehabilitative services are provided only until age 18 years. Despite every effort being made to recruit adults with CP for this study, the low response rate may have resulted in selection bias. In particular, adults with an interest in health promotion may

**Table 3** Regression coefficients (β) showing the association between cardiometabolic outcomes and anthropometric measures

| Dependent variable | Independent variable | Unstandardized coefficients, β (SE) | Standardized coefficients, β | *P* | $R^2$ change |
|---|---|---|---|---|---|
| HOMA-IR index | WC | 0.010 (0.003) | 0.501 | .001 | 0.183 |
| HOMA-IR index | BMI | 0.027 (0.008) | 0.448 | .002 | 0.176 |
| HOMA-IR index | WHR | 1.437 (0.484) | 0.526 | .005 | 0.150 |
| HOMA-IR | WHtR | 1.574 (0.459) | 0.456 | .001 | 0.184 |
| Triglycerides | WC | 0.020 (0.006) | 0.450 | .003 | 0.140 |
| Triglycerides | WHtR | 3.033 (0.993) | 0.407 | .004 | 0.135 |
| Triglycerides | WHR | 2.741 (1.033) | 0.452 | .011 | 0.108 |
| Triglycerides* | WC | 0.029 (0.012) | 0.648 | .016 | 0.090 |
| Triglycerides* | WHtR | 4.425 (1.837) | 0.593 | .020 | 0.084 |
| Systolic blood pressure | WC | 0.376 (0.151) | 0.352 | .016 | 0.084 |
| Systolic blood pressure* | WC | 0.599 (0.273) | 0.560 | .033 | 0.065 |

NOTE. The following model was used for all analyses: block 1: age, gender, ambulatory status; block 2: anthropometric measure. Each anthropometric measure was entered in a separate analysis to avoid multicollinearity. When systolic blood pressure or diastolic blood pressure was the dependent variable of interest, the analysis was additionally adjusted for self-reported taking of antihypertensive medication (coded as 1 if yes or 0 if no).

* Model additionally controlled for BMI in block 1.

**Table 4** Area under the curve values (95% confidence intervals) for anthropometric measures

| Risk Factor | BMI | WC | WHR[a] | WHtR |
|---|---|---|---|---|
| Hypertensive blood pressure | 0.693 (0.499–0.888) | 0.747* (0.533–0.961) | 0.726* (0.523–0.929) | 0.694 (0.483–0.906) |
| Hypercholesterolemia | 0.615 (0.451–0.778) | 0.643* (0.479–0.808) | 0.596 (0.422–0.769) | 0.611 (0.443–0.778) |
| Low HDL-C | 0.624 (0.407–0.842) | 0.692* (0.522–0.862) | 0.708* (0.523–0.893) | 0.711* (0.513–0.909) |
| High LDL-C | 0.666* (0.497–0.835) | 0.701* (0.527–0.875) | 0.688* (0.515–0.861) | 0.648* (0.472–0.825) |
| Hypertriglyceridemia | 0.754† (0.567–0.942) | 0.841† (0.693–0.988) | 0.757* (0.541–0.973) | 0.900† (0.813–0.988) |
| High HOMA-IR index | 0.700 (0.530–0.869) | 0.721† (0.521–0.920) | 0.657* (0.451–0.864) | 0.671 (0.480–0.862) |
| High-risk CRP | 0.600 (0.394–0.806) | 0.570 (0.381–0.759) | 0.605 (0.393–0.816) | 0.567 (0.374–0.759) |
| ≥2 risk factors | 0.665* (0.514–0.816) | 0.750† (0.609–0.892) | 0.706† (0.552–0.860) | 0.703† (0.552–0.853) |

NOTE. The Concordance C statistic (area under the curve) and Wald 95% confidence limits are provided for each analysis.
* $P<.05$.
† $P<.01$.

have been more likely to participate. Because information was not available on adults who did not respond to the recruitment efforts, comparisons cannot be made between responders and nonresponders. However, it should be noted that the sample size is similar to other studies of adults with CP. In addition, the small sample size did not allow for adjustment for gender when conducting ROC curve analysis. Only WC and WHR, however, are known to be associated with gender, and it is unlikely that performing separate analyses would change the order of the outcome. The results of the ROC curve analysis were also supported by the results of the regression analysis, which was adjusted for gender. Although an attempt was made to detect differences in cardiometabolic outcomes between ambulatory and nonambulatory adults, it is also possible that the sample size was not adequate to detect between-group differences.

## Conclusions

The results of this study indicate that relatively young adults with CP have clustering of cardiometabolic risk factors. Implementation of risk factor screening and preventive strategies is required in this population from young adulthood. WC is associated with hypertensive blood pressure, dyslipidemia, and insulin resistance in adults with CP regardless of age, gender, or gross motor functioning. WC provides additional information above that obtained from BMI. WC therefore presents as a quick and easy clinical measure, which should be used instead of or in conjunction with BMI, to identify adults with CP at risk of cardiovascular disease and type 2 diabetes mellitus. Future research should validate cutoffs for elevated waist circumference in adults with CP.

## Suppliers

a. Omron Healthcare UK Ltd, Opal Dr, Fox Milne, Milton Keynes, MK15 0DG, UK.
b. Roche Diagnostics GmbH, Friedrich-Ebert-Strabe 100, D-68298 Mannheim, Germany.
c. Analyse-it Software, Ltd, The Tannery, 91 Kirkstall Rd, Leeds, LS3 1HS, UK.
d. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.

## Keywords

Body mass index; Cardiovascular diseases; Cerebral palsy; Metabolic syndrome X; Rehabilitation; Risk factors; Waist circumference

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