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ORIGINAL REPORT

CARDIOVASCULAR DISEASE RISK IN ADULTS WITH SPASTIC BILATERAL CEREBRAL PALSY

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Objective: **To explore: (*i*) cardiovascular disease risk factors and the 10-year clustered risk of a fatal cardiovascular event in adults with spastic bilateral cerebral palsy; and (*ii*) relationships between the 10-year risk and body fat, aerobic fitness and physical activity.**

Design: **Cross-sectional study.**

Subjects: **Forty-three adults with spastic bilateral cerebral palsy without severe cognitive impairment (mean age 36.6 years (standard deviation 6); 27 men).**

Methods: **Biological and lifestyle-related risk factors and the 10-year risk according to the Systematic Coronary Risk Evaluation (SCORE) were assessed. Relationships were studied using multivariable linear regression analysis.**

Results: **The following single risk factors were present: hypertension ($n=12$), elevated total cholesterol ($n=3$), low high-density lipoprotein cholesterol ($n=5$; all men), high-risk waist circumference ($n=11$), obesity (body mass index; $n=5$; all men), reduced aerobic fitness (on average 80% of reference values), reduced level of everyday physical activity (on average 78% of reference values) and smoking ($n=9$). All participants had a 10-year risk < 1%. Corrected for gender, participants with higher waist circumference ($\beta=0.28$; $p=0.06$) or body mass index ($\beta=0.25$; $p=0.08$) tended to have a higher 10-year risk.**

Conclusion: **In this relatively young adult sample of people with spastic bilateral cerebral palsy several single cardiovascular disease risk factors were present. The 10-year fatal cardiovascular disease risk was low, and higher body fat tended to be related to higher 10-year risk.**

Key words: SCORE; blood pressure; lipid profile; waist circumference; physical fitness; cerebral palsy.

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INTRODUCTION

Cardiovascular disease (CVD) is a leading cause of morbidity and mortality worldwide, including in The Netherlands (1–3). Numerous studies of the general population have demonstrated that high body fat, low aerobic fitness and lack of physical activity are risk factors for CVD (4–6). Persons with chronic physical conditions, such as cerebral palsy (CP), may be at increased risk of developing CVD (7) because they have low levels of both aerobic fitness (8, 9) and everyday physical activity (10–13). Evidence for this hypothesis has been found in persons with spinal cord injury (7).

Nowadays, well-functioning persons with CP have a survival outlook close to that of the general population (14, 15) and CVD may become of increasing concern. Strauss et al. (14) demonstrated that mortality due to ischaemic heart disease and cerebrovascular disease were elevated in persons with CP, whereas Hemming et al. (15) found no such association.

Little is known about single CVD risk factors in CP. Some studies have been performed on body fat in adults, with conflicting results (16). In the USA and Korea, the number of ambulatory children with CP and overweight has increased over time (17, 18). Reduced levels of physical fitness have been found among children (9) and adults (8, 19) with CP. Low levels of everyday physical activity were demonstrated in children and adults with bilateral CP (11, 12), but not in adults with unilateral CP (20). On the other hand, Turk et al. (21) reported a low percentage of smoking (2%) among women with CP. To our knowledge comprehensive data concerning traditional CVD risk factors, such as blood pressure, lipid profile and diabetes mellitus in adults with CP, are scarce (22).

Exploring single CVD risk factors is necessary to obtain insights into condition-specific problems and preventive strategies. Apart from single risk factors, it is important to investigate clustered risk, because it estimates CVD risk better than the sum of separate risk factors (23). In adults with CP, there are no objective data about clustered CVD risk.

The aims of the present study were to investigate biological and lifestyle-related CVD risk factors, and to assess the clustered 10-year risk of a fatal cardiovascular event in adults with spastic bilateral cerebral palsy (SBCP), aged 25–45 years, without severe cognitive impairment. Furthermore, as body fat, aerobic fitness and everyday physical activity are modifiable factors from an exercise perspective, we explored associations between the 10-year risk and these factors. Because it is

important to explore cardiovascular risk and begin preventive strategies early in life, a relatively young adult sample was studied (3, 5).

METHODS

Study sample

Participants were recruited from 10 rehabilitation centres in The Netherlands, including historical paediatric registers, and via the Association of Physically Disabled Persons and their Parents (BOSK). The inclusion criteria were: a diagnosis of SBCP and age 25–45 years. Exclusion criteria were: (*i*) any multimorbidity with lasting effects on everyday physical activity or contraindicated for a progressive maximal ergometer test; (*ii*) full dependence on powered wheelchair propulsion; (*iii*) inadequate Dutch language proficiency; (*iv*) legal inability, which refers to persons who are not able to grant consent for participation; and (*v*) severe cognitive impairment according to medical files. This criterion excluded persons who could not understand study instructions.

This study was part of a larger cross-sectional study in 56 participants on daily functioning and physical fitness (24). Prior to this larger study, 6 persons were excluded because of multimorbidity, including severe lung disease. From the original cohort of 56 participants (24), 13 could not participate in the present study due to no consent to blood withdrawal ($n = 12$) and missing values for blood pressure ($n = 1$). Therefore, 43 adults with SBCP participated in the present study. In a non-response study, participants were older than non-participants (mean difference 2.7 years; $p < 0.05$), but there was no difference regarding gender or distribution of limb impairment. All participants received verbal and written information about the study and gave their written consent to participate. The study was approved by the medical ethics committee of the Erasmus Medical Center and the participating rehabilitation centres.

Measurements

Characteristics of study sample. Neuromotor abnormality was classified according to the Reference and Training Manual of the Surveillance of CP in Europe (SCPE) (25), and gross motor functioning according to the Gross Motor Function Classification System (GMFCS) (26). Age, gender, ethnicity, level of education, employment and civil status were reported. For each participant the medical and family history of hypertension, CVD and diabetes mellitus, and the use of antihypertensive, lipoprotein metabolism and anti-diabetic drugs were recorded.

Biological risk factors. Blood pressure was measured while the participants were seated for 10 min prior to the measurement. Using a sphygmomanometer (Maxi Stabil, Speidel&Keller, Jungingen, Germany) and appropriately sized measure cuff, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured twice and mean values were recorded. Blood pressure was classified according to the 7th report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure (JNC 7) (2).

Total serum cholesterol (TC), high-density lipoprotein cholesterol (HDL-C) and glucose were measured by taking non-fasting venous blood samples of approximately 10 ml from the vena antecubitis with a vacutainer. Their concentrations were determined using routine methods on a Roche Modular analyser (Roche Diagnostics, Almere, The Netherlands). Values of lipids were categorised according to the National Cholesterol Education Program, Adult Treatment Panel III (NCEP ATP III) (27) and glucose according to well known non-fasting cut points (3, 28). Non-fasting samples were used, which is allowed for CVD risk estimation (1, 27).

As indicators of body fat, waist circumference and body mass index (BMI) were assessed. Waist circumference was measured midway between the lower rib margin and the iliac crest, with the tape positioned evenly around the bare abdomen (1, 28) while the participant was lying supine instead of standing. The mean waist circumference of 2 measurements was recorded in centimetres. Standing waist circumference was calculated from the supine waist circumference by the correction equation of Waninge et al. (29) and classified according to Lean et al. (30). BMI (kg/m^2) was calculated and classified according to the World Health Organization (WHO) criteria on BMI (1, 3). Height was measured while lying supine, in case of contractures from joint to joint. Weight was measured on a digital chair scale (Cormier, type H.F., France).

Aerobic fitness was measured during a progressive maximal exercise test on an electronically braked cycle ergometer (Jaeger ER 800, Jaeger Toennies, Breda, The Netherlands) by a portable breath-by-breath gas analyser (K_4b^2, Cosmed, Rome, Italy). Detailed descriptions of this test, based on the McMaster All-Out Progressive Continuous Protocol, can be found elsewhere (8). Aerobic fitness was operationalised as the mean oxygen uptake during the last 30 s of exercise (VO_{2peak}, expressed in l/min). The cycle ergometer test was performed in 35 participants. Eight participants were excluded because of severe hypertension ($n = 1$), missing values ($n = 2$) and inability to cycle ($n = 5$, due to severe spastic paresis, impaired balance and/or osteoarthritis).

Lifestyle-related risk factors. The level of everyday physical activity was objectively measured during 2 consecutive weekdays using an accelerometry-based activity monitor (AM; Temec Instruments BV, Kerkrade, The Netherlands) (11, 13). The level of everyday physical activity was operationalised as the mean duration of dynamic activities (composite measure of the separately detected activities walking (including walking stairs and running), wheelchair propulsion, cycling, and general non-cyclic movement) of the 2 measurement days, expressed in min/day.

Smoking behaviour and alcohol consumption were assessed in a face-to-face interview. We recorded smoking (yes/no), and classified the level as heavy smoking (≥20 cigarettes (cig)/day) or not (28). Drinking alcohol was classified as never, light (1 drink/day), intermediate (> 1–<3 drinks/day) or heavy (≥3 drinks/day) (28).

European Systematic Coronary Risk Evaluation (SCORE). Following the current European and Dutch guidelines for primary prevention of CVD, the individual 10-year absolute risk of a fatal atherosclerotic event including heart attack, stroke, or aortic aneurysm was estimated by using SCORE (1, 31). SCORE is a CVD risk assessment model based on a large data-set tested thoroughly on European data (23). It takes an individual's overall risk profile into account and estimates the clustered 10-year CVD risk directly. The individual SCORE-risk was calculated for all participants according to the equation of the original reference (23), which includes the risk factors age, gender, TC, mean SBP, and cigarette smoking. The SCORE low-risk equation was used, which is applicable for regions with a low CVD risk in Europe, including The Netherlands (32).

Dutch reference samples. Blood pressure, TC, HDL-C, TC/HDL-C ratio, glucose, BMI, smoking and alcohol behaviour were compared with Dutch reference values obtained using comparable measurement procedures, e.g. non-fasting blood samples and similar age groups. From a total of 22,769 persons, different subgroups, all aged 20–49 years, were selected according to the risk factor studied (28). Aerobic fitness was compared with reference values obtained from a healthy, untrained sample from the USA, Canada and 7 European countries (including The Netherlands) (33) and expressed as a percentage of these reference values. Everyday physical activity was compared with reference values of healthy age-mates from our own database and measured with the same AM protocol ($n = 45$) (11, 13), and expressed as a percentage of these reference values. Reference values are presented in Table II and compared with values of persons with SBCP in the discussion.

Statistical analysis

Data were analysed using SPSS, version 17.0 (SPSS Inc., Chicago, IL, USA). All categorised results were tested by χ^2 tests. Subgroup analyses were performed with the *t*-test for independent samples (gender) or with one-way analysis of variance for means and the χ^2 test for proportions (GMFCS level in 3 subgroups: I, II and III/IV). In case of skewed variables the Mann-Whitney *U* test or Kruskal-Wallis test were used. In Tables II and III the results are presented for gender, but not for GMFCS level, because the latter showed significant differences for only 2 risk factors. *p*-values below 0.05 were considered statistically significant.

Linear regression analysis was used to study associations. SCORE, waist circumference, BMI, aerobic fitness and level of everyday physical activity were treated as continuous variables. GMFCS level was treated a categorical variable and dichotomized in subgroups I/II and III/IV. Multivariable linear regression analyses were performed for exploring associations with SCORE low-risk (dependent variable). Separate regression analyses were conducted for each of the following independent variables, one at a time and corrected for gender (1, 23): GMFCS level, and the risk factors waist circumference, BMI, aerobic fitness or everyday physical activity, which are not included in SCORE. Similarly, multivariable linear regression analyses were conducted, with SBP or DBP as dependent variables, and waist circumference, BMI, aerobic fitness or everyday physical activity as independent variables, corrected for gender.

To compare the influence of variables with a different scale, standardised regression coefficients (Beta, β) were calculated, expressing the influence of a shift of 1 SD of the variables on the outcome of interest. Beta, confidence intervals (95% CI) and explained variance (R^2; %) are reported.

Table I. *Characteristics of the study sample with spastic bilateral cerebral palsy (*n = *43)*

Characteristics	
Age, years, mean (SD)	36.6 (6)
Gender: men, *n*	27
Ethnicity: Caucasian, *n*	43
Limb distribution, *n*	
Diplegia	23
Quadriplegia	20
GMFCS, *n*	
Level I	11
Level II	22
Level III	8
Level IV	2
Level V	0
Level of education[a], *n*	
High	15
Medium	18
Low	10
Student/employment status, *n*	
Student	2
Competitively employed	25
Sheltered employed	4
Disability pension, including volunteer work	12
Civil status, *n*	
Married/living together	9
Single	34

[a]Levels of education: Low: no education or elementary school and pre-vocational practical education; Medium: pre-vocational theoretical education and upper secondary vocational education (vocational high school); High: secondary education, higher education and university.
SD: standard deviation.

RESULTS

Characteristics and medical history of the study sample

Characteristics of the study sample are presented in Table I. None of the adults with SBCP had a medical history of CVD or diabetes mellitus. Two adults had a medical history of hypertension, both of whom used antihypertensive drugs prior to the study. No participants used lipoprotein metabolism drugs. The family medical history was known for 39 participants, of whom 6 participants had positive kindreds (6 CVD, 2 diabetes mellitus).

Biological and lifestyle-related risk factors for CVD

Descriptive results of single biological and lifestyle-related risk factors for the participants with SBCP and the Dutch reference samples are shown in Table II. According to classifications of CVD risk factors (2, 3, 27) (Table III), several risk factors were present in some of the participants: hypertension ($n = 11$); elevated levels of TC ($n = 3$); and high waist circumference ($n = 11$). Risk factors present only in men with SBCP were: low HDL-C ($n = 5$), representing a major risk; and obesity based on BMI ($n = 5$). All adults with SBCP had normal blood glucose levels. Levels of aerobic fitness (mean 79.7% (SD 12.8) of reference values) and everyday physical activity (mean 78.4% (SD 35.9) of reference values) were both reduced in the participants.

Subgroup analyses showed a significant difference between men and women with SBCP for waist circumference based on categories ($p = 0.02$) (Table III). In addition to obesity, underweight was present only in men (Tables II and III). Women with SBCP had significantly more favourable scores for DBP, HDL-C, TC/HDL-C ratio and VO_{2peak} (expressed as a percentage of reference values) than men with SBCP (Table II). For GMFCS level, 2 differences were found: more study participants in GMFCS level II than in levels I and III/IV had hypertension ($p < 0.001$), and a lower level of everyday physical activity was noted in participants with GMFCS level III/IV (82.0 min/day (SD 43.8)) than with GMFCS level I (148.7 min/day (SD 41.3) ($p = 0.009$).

Ten-year risk, blood pressure and associations with body fat, aerobic fitness and everyday physical activity

All adults with SBCP had a SCORE risk of < 1%, which equates to a low 10-year risk of fatal CVD (Table II). The risk for women was lower than for men ($p = 0.001$). Corrected for gender, participants with a higher waist circumference tended to be more likely to have a higher 10-year risk ($\beta = 0.28$, $p = 0.06$) (Table IV). Using BMI in the multivariable analysis gave comparable results ($\beta = 0.25$, $p = 0.08$). No associations were demonstrated between VO_{2peak} or everyday physical activity and 10-year risk.

Considering the high proportion of participants with (pre) hypertensive values (Table III), we explored modifiable factors associated with blood pressure (2) by multivariable linear regression analyses. Mean DBP, but not mean SBP, was as-

Table II. *Biological and lifestyle-related risk factors of cardiovascular disease and 10-year fatal cardiovascular disease risk in adults with spastic bilateral cerebral palsy and Dutch reference samples*

	Adults with CP ($n=43$)		Men vs women with CP	Reference sample ($n=$[a])	
	Men ($n=27$)	Women ($n=16$)	p-value	Men ($n=$[a])	Women ($n=$[a])
Biological risk factors					
Blood pressure					
Systolic, mmHg, mean (SD)	126 (10)	126 (10)	0.98	122	113
Diastolic, mmHg, mean (SD)	86 (11)	81 (6)	0.03	77	73
Hypertension, Systolic ≥140, Diastolic ≥90, mmHg, *n*, %	8 (30)	3 (19)	0.50	15	8
Blood lipid and lipoproteins, mean (SD)					
Total cholesterol, mmol/l	4.7 (0.8)	5.0 (0.9)	0.18	5.0	4.9
High-density lipoprotein, mmol/l	1.3 (0.4)	1.8 (0.5)	<0.01	1.2	1.5
Total cholesterol/HDL ratio	3.8 (1.4)	2.9 (0.8)	0.005	4.6	3.5
Glucose, mmol/l, mean (SD)	4.1 (0.8)	4.7 (1.1)	0.06	5.2	5.0
Body fat, mean (SD)					
Waist circumference, cm	87.8 (16.2)	80.9 (9.9)	0.09	NA	NA
Body mass index, kg/m^2	24.3 (6.0)	23.5 (3.0)	0.60	24.7	24
BMI ≥30, %	5 (18.5)	0 (0)	0.07	7.2	8
Aerobic fitness, $n=35$[b]					
VO_{2peak}, l/min, mean (SD)	2.4 (0.4)	1.7 (0.3)	<0.01	3.1 (0.14)	2.0 (0.14)
VO_{2peak} as percentage of reference values[c], %	76.1 (11.5)	86.5 (12.8)	0.02		
Lifestyle-related risk factors					
Physical activity, min/day, mean (SD)	108.6 (49.3)	127.0 (59.4)	0.28	135.5 (46.1)[d]	175.0 (46.9)[d]
Physical activity as percentage of reference values, %	81.9 (37.2)	72.6 (34.0)	0.42		
Current smoker, yes, *n*, %	7 (26)	2 (13)	0.30	39	39
Smoking behaviour, ≥20 cig/day	1 (4)	0 (0)	0.44	36	32
Alcohol drinking never, *n*, %	11 (41)	11 (69)	0.08	9	18
Alcohol light drinking, 1 drink/day, *n*, %	12 (44)	4 (25)	0.20	35	57
Alcohol intermediate drinking, >1–<3 drinks/day, *n*, %	4 (15)	1 (6)	0.4	37	21
Alcohol heavy drinking ≥3 drinks/day, *n*, %	0 (0)	0 (0)	NA	19	4
Clustered 10-year fatal CVD risk					
SCORE risk, %, mean (SD)	0.19 (0.18)	0.06 (0.06)	0.001	NA	NA

[a]From a total of $n=22,769$ persons of the Dutch general population, subgroups (aged 20–49 years) were selected according to the risk factor studied (28).
[b]Aerobic fitness was measured in 35 participants.
[c]According to Shvartz & Rebold (33).
[d]Able-bodied age mates ($n=45$, age±5 years) measured with the same activity monitor protocol (11, 13).
NA: not available; SD: standard deviation; BMI: body mass index; CVD: cardiovascular disease risk; SCORE: Systematic Coronary Risk Evaluation.

sociated with waist circumference ($\beta=0.34$, $p=0.03$) and BMI ($\beta=0.36$, $p=0.02$) after correcting for gender. No associations were demonstrated with aerobic fitness (SBP: $\beta=0.15$, $p=0.51$; DBP: $\beta=0.27$, $p=0.21$) or everyday physical activity (SBP: $\beta=0.02$, $p=0.91$; DBP: $\beta=0.001$, $p=0.10$).

DISCUSSION

This sample of adults with SBCP without severe cognitive impairment, aged 25–45 years, had a 10-year fatal cardiovascular risk of <1%. Although this is a low 10-year risk, several single biological and lifestyle-related risk factors were present in the relatively young study sample.

In total, 12 (28%) participants had hypertension, including one person with a medical history of hypertension, who used antihypertensive drugs prior to our study, resulting in prehypertensive values. Prehypertensive values were found in another 44% of the participants, which makes them at increased risk for progression to hypertension (2). The study sample had a higher blood pressure than a Dutch reference sample (28), including a two-fold higher hypertension rate in men with SBCP. The high proportion of participants with (pre)hypertensive values underlines the importance of regularly measuring and managing blood pressure from young adulthood onwards.

Obesity according to BMI was reported more often in men with SBCP than in men in the reference group. A high waist circumference was present in 26% of the participants. The adults with SBCP had reduced levels of both aerobic fitness and everyday physical activity (expressed as a percentage of reference values). These findings suggest the importance of controlling the risk factors body fat, aerobic fitness and physical activity in individuals with SBCP. In contrast to the aforementioned, all adults with SBCP had normal levels of glucose. Furthermore, in comparison with the Dutch reference sample (28), the lipid profile was more favourable in the study sample. Considering the level of underweight, dietary factors might play a role in this finding. In addition, less smoking and alcohol consumption were reported in adults with SBCP than in the reference group. Alcohol use among the adults with SBCP was light or intermediate, not heavy. Therefore an increased risk of CVD based on alcohol consumption is unlikely.

Corrected for gender, participants with a higher waist circumference or BMI tended to have a higher 10-year fatal CVD risk. This trend is in line with results of other studies on

Table III. *Categorised cardiovascular disease risk factors in adults with spastic bilateral cerebral palsy (*n = *43)*

	Men (n=27) n	Women (n=16) n	p-value
Blood pressure: systolic/diastolic, mmHg[a]			
Normative <120/80	7	5	0.31
Prehypertension 120–139/80–89	12	8	
Stage I hypertension 140–159/90–99	3	3	
Stage II hypertension ≥160/100	5	0	
Total cholesterol, mmol/l[b]			
Desirable <5.2	19	10	0.55
Borderline high 5.2–6.2	7	4	
High ≥6.2	1	2	
High-density lipoprotein, mmol/l[b]			
High (no risk) ≥1.56	7	10	0.03
In between 1.04–1.55	15	6	
Low (major risk) <1.04	5	0	
Glucose, mmol/l			
Normal <7.8	27	16	NA
Impaired >7.8 –<1 1.0	0	0	
Indication diabetes mellitus >11.0	0	0	
Waist circumference, cm[c]			
Underweight: women: <68, men: <79	10	0	0.02
Normal: women: ≥68–<80, men: ≥79 –<94	5	8	
Increased: women:> 80–<88, men: >94–<102	6	3	
High-risk: women: ≥88, men: ≥102	6	5	
Body mass index, kg/m^2[d]			
Underweight <18.5	4	0	0.07
Normal ≥18.5 –24.9	13	13	
Overweight ≥25.0–29.9	5	3	
Obese ≥30.0	5	0	

[a]According to the seventh report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure (2).
[b]According to the ATP III definitions of the third report of the National Cholesterol Education Program (27).
[c]According to the classification of Lean et al. (30).
[d]According to World Health Organization (WHO) criteria (1, 3).
NA: not available.

Table IV. *Multivariable analysis among adults with spastic bilateral cerebral palsy (*n = *43): relationships between 10-year cardiovascular disease (CVD) risk (Systematic Coronary Risk Evaluation (SCORE), dependent variable) and 1 independent variable (Gross Motor Function Classification System (GMFCS)), body fat, aerobic fitness or everyday physical activity) corrected for gender*

		Multivariable analysis	
Independent variables n=43	Beta	95% CI	R^2 (%)
Gender	–0.42	–0.71 to –0.14	17.6
GMFCS	0.01	–0.26 to 0.29	
Gender	–0.34	–0.62 to –0.06	24.5
Waist circumference, cm	0.28	–0.01 to 0.56	
Gender	–0.40	–0.67 to –0.13	23.8
BMI, kg/m^2	0.25	–0.02 to 0.52	
Gender	–0.47	–0.87 to –0.07	21.1
VO_{2peak}, l/min, n=35	–0.01	–0.40 to 0.37	
Gender	–0.41	–0.69 to –0.13	17.8
Physical activity, min	–0.05	–0.33 to 0.23	

Beta: standardised regression coefficient; CI: confidence interval; R^2: represents explained variance.

body fat and CVD risk in the general population (1, 5, 6). We found no evidence for associations between aerobic fitness or everyday physical activity and 10-year risk. This absence of associations might be due to the relatively young age of the study sample and attendant low 10-year risk. Other possible explanations for the lack of associations are the relatively small sample size and the rather mildly affected sample (mainly GMFCS I and II, partly due to exclusion of persons dependent on powered wheelchair propulsion or unable to perform cycle ergometry). Inclusion of more severely affected persons might have produced broader ranges of aerobic fitness and/or everyday physical activity, as well as possible associations with the 10-year CVD risk. Finally, aerobic fitness and everyday physical activity could also influence CVD risk through indirect effects not covered by SCORE, in view of the known interrelationships among CVD risk factors (2, 4, 5). Similar arguments might play a role in the lack of associations between blood pressure and aerobic fitness or everyday physical activity. The association demonstrated between diastolic blood pressure and waist circumference suggests a contribution of abdominal obesity in developing high blood pressure in CP. Other factors in CP that might contribute to an increased risk of hypertension and CVD are muscle atrophy and intramuscular adiposity (7, 22). The presence of these factors from an early age onwards may lead to metabolic dysregulation (endocrine disturbances, such as insulin resistance) and low-grade inflammation similar to general populations (7). Considering this, an earlier onset of atherosclerotic vascular disease in CP might be hypothesized. However, a recent study between a small sample of ambulatory youth with CP with low levels of physical activity and a healthy reference sample demonstrated no differences in arterial health (34). To our knowledge, arterial structure and function has not been studied in adults with CP. The higher proportion of hypertensive values demonstrated in GMFCS level II is probably a coincidence, as this category contains the largest number of study participants.

In a meta-analysis of general populations, Williams (35) reported that aerobic fitness and physical activity have significantly different relationships to CVD. The reductions in relative risk were nearly twice as great for aerobic fitness as for physical activity. In more recent studies of general populations, aerobic fitness (36) but not everyday physical activity (5) was predictive for a healthy CVD risk profile later in life. For instance, in a Dutch study by Twisk et al. (5), aerobic fitness during adolescence was related to a healthy CVD risk profile at the age of 32 years, whereas everyday physical activity was not. However, it should be noted that methodological aspects (e.g. using questionnaires to assess everyday physical activity) might have influenced the above findings.

Study limitations

The studied sample was relatively small. A larger sample would give a more precise estimate of CVD risk. However, we put maximal effort into attaining a representative sample, e.g. by extensive recruitment among a broad population. Gender, level of education, and GMFCS level were comparable to adults with

SBCP without severe cognitive impairment in a representative cohort from the same geographical region (37).

Some caution is needed in interpreting the measurements. First, non-fasting blood samples were used for practical reasons, which may lead to an overestimation of the CVD risk. However, the levels of TC and HDL-C are minimally altered when measured in fasting or non-fasting blood (38). Furthermore, there is growing evidence that HDL-C and TC/HDL-C ratio predict CVD when measured under non-fasting conditions (38, 39). For the associations of fasting or non-fasting TC with CVD conflicting results were found (38, 39). The Dutch guidelines on cardiovascular risk management recommend measurement of a fasting lipid profile and glucose, but allow non-fasting values for the estimation of CVD risk, including screening of the glucose level (1). The SCORE steering committee of the European Society of Cardiology and the NCEP guidelines (27) allow measurement of non-fasting TC and HDL-C as well. Thus, for the purpose of our study (estimation of CVD risk), non-fasting samples are allowed.

Secondly, our study included all risk factors according to Dutch guidelines (1), except dietary pattern, which somewhat hampers interpretation of our findings. Thirdly, height and waist circumference were measured in all participants while lying supine, so as to obtain accurate measurements in case of deformities of the limbs or restrictions in standing. The underscoring of height in our study may partly explain the higher proportion of men who were underweight based on waist circumference than on BMI. Because no classification exists for measurements recorded in the supine position, we predicted the standing waist circumference by the correction equation of Waninge et al. (29) and classified waist circumference according to Lean et al. (30). A limitation of this equation is that it is derived from a small and severely affected sample with various disorders, however, including CP. Recently, Peterson et al. (22) demonstrated that waist-to-hip ratio was associated with several markers for dyslipidaemia in adults with CP, whereas BMI and waist circumference were not associated with these markers. Furthermore, it was suggested that BMI may be healthy in persons with CP despite the fact that they have excessive body fat, because of muscle atrophy and diminished bone density. Considering the problems of measuring waist circumference and BMI in CP, both were used in the multivariable analyses and showed comparable results.

Finally, other parameters (e.g. energy expenditure, sedentary time) or longer durations of measurement might deepen our understanding of everyday physical activity and its potential association with CVD risk. However, our aim was not to characterize habitual physical activity, but to obtain insight into the level of everyday physical activity. Therefore, monitoring during 2 randomly selected weekdays in both persons with CP and the reference sample is considered to be an adequate duration to reliably record activities (13, 40).

Study strengths

Strengths of the study are the extensive objective measurements of CVD risk, unlike in other studies where questionnaires are often used, e.g. to assess physical activity. The study fills a gap in the literature on biological and lifestyle-related CVD risk factors and the clustered CVD risk in adults with CP.

Conclusion

In this sample of relatively young adults with SBCP the 10-year fatal CVD risk was low, but several single CVD risk factors were present, of which (pre)hypertensive blood pressure was prominent. A higher level of body fat tended to be related to a higher 10-year risk, but no relations were demonstrated with aerobic fitness or everyday physical activity.

Further research is warranted with other measures (e.g. sedentary time, energy expenditure) and/or a different sample (more severely affected persons, older ages) to obtain more insight into CVD risk and its relationships with modifiable factors. Thus far, the current findings highlight the importance of screening for CVD risk factors in SBCP, specifically blood pressure and body fatness, and to start preventive strategies from young adulthood onwards.

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