






# BMJ Open Predictors of physical activity levels in children and adolescents with cerebral palsy: clinical cohort study protocol

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## ABSTRACT

**Introduction** Children and adolescents with cerebral palsy may be trapped in a vicious circle of low physical fitness, resulting in deconditioning that causes a further decrease in physical activity (PA), a lower quality of life and an increased risk of developing non-communicable diseases. Therefore, establishing a healthy and active lifestyle during childhood is even more important for individuals with a disability. However, the factors that influence habitual PA in children and adolescents with cerebral palsy remain unknown.

The present protocol outlines a prospective cohort study with the aim of investigating potential predictors of habitual PA in children and adolescents with cerebral palsy in order to provide evidence for optimising PA levels and associated overall health.

**Methods and analysis** This prospective cohort study will enrol participants with cerebral palsy between the ages of 8 and 15 years at Gross Motor Function Classification System levels I–III. Using a modified version of the International Classification of Functioning, Disability and Health model as a conceptual analytical framework, the analysis will be divided into six components and will provide predictors for habitual PA measured by accelerometry. The potential predictive variables are registry data on physical function (Danish Cerebral Palsy Follow-Up Programme); validated proxy-reported questionnaires on quality of life (Paediatric Quality of Life Inventory), overall health, pain and participation in daily activities (Paediatric Outcomes Data Collection Instrument) and supplementary questions regarding sleep, screen time and socioeconomic status.

**Ethics and dissemination** The project is approved by the Danish Data Protection Agency (19/16396) and has been declared not notifiable by the Regional Committee on Health Research Ethics, cf. Committee Act Art. 14, paragraph 1 (S-20192000-23). The study results will be published in international peer-reviewed journals, presented at international conferences, and published in a PhD dissertation.

**Trial registration number** NCT04614207.

## INTRODUCTION

### Cerebral palsy

Cerebral palsy (CP) is a condition that describes a group of disorders (altered muscle tone, movement disorders, muscle weakness,

## Strengths and limitations of this study

- The study will provide novel evidence that will aid identification of physical activity (PA) levels and patterns in children and adolescents with cerebral palsy for early intervention.
- The findings may be implemented in evidence-based PA guidelines, which currently are lacking for children and adolescents with cerebral palsy.
- Bootstrap validation will be performed to increase internal validation. Optimally, external validity of the findings should be verified in the future using an external cohort.

ataxia and rigidity) related to the development of movement and posture causing activity limitations and reduced quality of life (QoL).<sup>1</sup> CP is a common impairment among children, with a prevalence of 2.1 per 1000 live births worldwide<sup>2</sup> and 2.4 per 1000 live births in Denmark.<sup>3</sup> CP is attributed to non-progressive disturbances in the fetal central nervous system or in the developing infant within the first 2 years of life.<sup>1,4</sup> Although CP is a non-progressive diagnosis, it is a lifelong condition that requires attention through most of the person's life, as impairments are constantly evolving and inhibit performance of activities and participation in daily living.<sup>1,5</sup>

## Physical activity

Low levels of physical activity (PA) are a worldwide threat to the health of children, including those with disabilities. For this reason, WHO recommends children to be moderate to vigorous physical active for at least 60 min per day, including muscle-strengthening and bone-strengthening activities at least 3 days per week.<sup>6</sup> Although there are no specific evidence-based PA guidelines for children with CP, it is clear that they have lower levels of PA and higher levels of time spent sedentary than their peers<sup>7</sup> and that

their level of mobility limitation is negatively associated with their level of PA.<sup>8</sup>

The long-term effects of reduced habitual PA and increased sedentary time include a greater risk of developing non-communicable diseases such as metabolic dysfunction, cardiovascular disease and poor bone density. These problems can, in turn, result in poorer overall health, reduced life expectancy and a greater burden of disease in years of life lost to disability.<sup>9 10</sup> Furthermore, evidence suggests that more than 25% of adults with CP experience mobility decline, for some resulting in persistent loss of independent gait function, thus, emphasising the importance of maintaining a physical active lifestyle throughout childhood and adolescence.<sup>11</sup> Ideally, childhood should be marked by high levels of intense play and habitual PA, which, in addition to providing protective physical benefits, also appears to improve mental health.<sup>12 13</sup>

### Predictors of PA

In Scandinavia, healthcare professionals offer standardised clinical examinations throughout childhood using the Cerebral Palsy Follow-Up Programme (CPUP), which was developed in Sweden more than 20 years ago<sup>14</sup> and was adopted in Denmark as a National Clinical Quality Database by the Danish Clinical Registries in 2015. CPUP is designed to support early detection of complications, such as hip dislocation, scoliosis and muscle contracture, as well as to improve the quality of healthcare.<sup>14 15</sup> Danish clinical guidelines for physiotherapy and occupational therapy for children with CP emphasise that future research should focus on the short-term and long-term effects of the interventions applied to improve the children's activities of daily living.<sup>16</sup> Despite this recommendation, it has not been investigated whether the standardised examinations and accompanying variables of CPUP are associated with habitual PA. Thus, potential objective predictors of PA can be identified through this national clinical quality database, allowing early detection and potentially improved interventions.

To optimise activities of daily living and long-term health outcomes for the present population, a key objective is to encourage and facilitate an increase in habitual PA and reduce the amount of time spent sedentary.<sup>7</sup> However, the current literature does not provide evidence for barriers to or motivators for PA in children and adolescents with CP. Furthermore, no studies have examined the underlying reasons for altering habitual PA.

### Aim and hypothesis

The aim of the present cohort study is to identify and investigate potential predictors of habitual PA in children and adolescents with CP, with the perspective of providing evidence to optimise PA levels and associated overall health.

We hypothesise that potential predictors of habitual PA can be identified through objective variables included in the CPUP database and in supplementary questionnaires

on proxy-reported outcome measures, using a modified International Classification of Functioning, Disability and Health (ICF) model (Body Functions and Structures, Activities, Participation, Personal Factors, Environmental Factors and QoL) as a conceptual statistical framework.

## METHODS AND ANALYSIS

### Study design

A prospective clinical cohort study using historical registry data from CPUP and supplementary proxy-reported outcome measures will be conducted. The STrengthening the Reporting of OBservational studies in Epide-miology (STROBE) checklist for reporting cohort studies will be used to report the study findings.<sup>17</sup> Enrolment commenced on 3 November 2020 and is expected to end by December 2021.

### Ethics and dissemination

The project has been approved by the Danish Data Protection Agency (19/16396) and has been declared not notifiable by the Regional Committee on Health Research Ethics, cf. Committee Act Art. 14, paragraph 1 (S-20192000-23). The Danish Clinical Registries granted access to the CPUP database in June 2019.

The project will be conducted in accordance with the Declaration of Helsinki II. Before participants (parents/guardians) give their informed written consent to take part in the study, they will receive written and oral information on the experimental procedure and potential risks. The families will be informed that they can withdraw from the study at any time. All subject data will be treated confidentially and in confidence according to the European Union's General Data Protection Regulation.

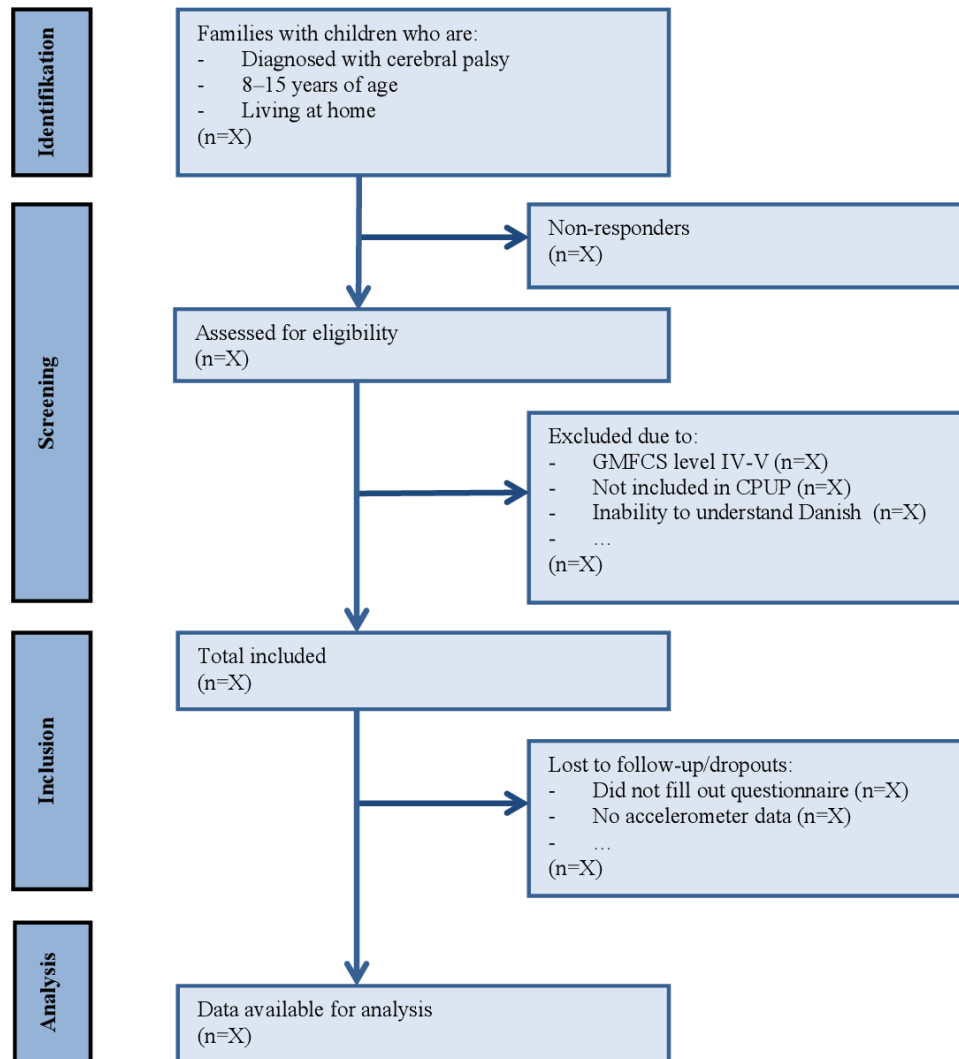
The study results, whether positive, negative or inconclusive, will be published in international peer-reviewed journals, presented at international conferences and published in a PhD dissertation. The articles and presentation will not contain any information that could lead to identification of any participants.

### Participants and study setting

Participants will be recruited from the five regions of Denmark.

To increase the external validity and sample size of the present project, the inclusion criteria will include children and adolescents of 8–15 years (born between 1 January 2003 and 31 December 2013) who are diagnosed with CP. Inclusion via invitation commenced on 3 November 2020.

The children/adolescents must be registered in the Danish CPUP and classified at Gross Motor Function Classification System (GMFCS) levels I–III, demonstrating an independent gait function with or without mobility devices. A flow diagram of participants through the study is illustrated in [figure 1](#). Parents/guardians must be able to read and understand Danish.



**Figure 1** Flow diagram. GMFCS, Gross Motor Function Classification System.

Eligible participants will be identified through the Danish Health Data Authority, after which the parents/guardians will receive written information through secure digital post (e-Boks). If clarification is needed, the project manager can be contacted via telephone or email. Interested parents/guardians will consent electronically via personal link in e-Boks and will automatically be forwarded the questionnaires, which will be filled out electronically. For non-responders, an email reminder will be sent out a total of three times. Habitual PA is to be measured using accelerometers (see below for further description). Participants will receive an accelerometer via postal mail, including a prepaid return envelope.

### Data sources and measurements

Parents'/guardians' perceptions of their child's activity behaviour, health status, sociodemographic background, sleep and screen habits will be collected in an electronic questionnaire. Demographic characteristics (age, sex, CP type and subtype, GMFCS level) and detailed information on the participants' health and physical abilities, as evaluated by healthcare professionals, will be collected

through CPUP (see below for further description of collected variables).

The patient-reported outcome measures will be entered directly into a secure web database, Research Electric Data Capture (REDCap), under Open Patient data Explorative Network (OPEN), Odense University Hospital, Region of Southern Denmark,<sup>18</sup> by the parents/guardians using a web link sent via secure digital post (e-Boks). Legal values have been set where possible, to validate the entered values. All collected data will be stored in OPEN Storage, merged and analysed at the Danish Health Data Authority Research Engine.

### Quantitative variables

#### Accelerometry

Habitual PA will be assessed using the Axivity AX3 accelerometer. The use of an accelerometer is a common method for objectively measuring PA,<sup>19</sup> and is considered a feasible and validated measure for ambulatory children and adolescents with CP.<sup>20</sup>

The Axivity AX3 detects movement in three directions: vertical (X), anteroposterior (Y) and mediolateral (Z).



The combination of these three axes allows for movement to be calculated into vector magnitude (VM), with  $VM = \sqrt{(X^2 + Y^2 + Z^2)}$ . VM will be calculated per epoch of time in activity counts (counts per epoch of time). Sampling frequency will be set at 50 Hz with a dynamic range of  $\pm 8g$ .<sup>21</sup> The collected raw data will provide information on the wearer's habitual PA behaviour regarding acceleration of bodily movement.

The accelerometer is to be worn in a snug-fitting pouch in an elastic belt, strapped around the hip, with the device placed on the midaxillary line at the level of the iliac crest on the child's right side.<sup>19 22</sup> The accelerometer device is to be worn for seven successive days; five school days and a weekend.<sup>23</sup> A valid wear day will be defined as a day where the accelerometer is worn for at least 10 hours out of the expected awake time (defined as hours between 6:00 and 22:00 hours on weekdays, and 7:00 and 23:59 hours on weekend days). A similar method has been used in the study by Rasmussen *et al*.<sup>21</sup> to assess non-sedentary time with screen time use.<sup>21</sup> The minimum number of valid wear days will be four, including 1 weekend day.<sup>24</sup> According to procedures used in previous studies<sup>21</sup> non-wear periods are identified and registered as missing data by evaluating three signal features generated from acceleration in combination with temperature and predefined expected awake time. Periods of no movement (acceleration below 20 mg) will be identified as non-wear depending on the timespan: (1) periods longer than 120 min will always be identified as non-wear, (2) periods from 45 to 120 min are identified as non-wear if the average temperature is below an individually estimated non-moving temperature (NMT) threshold and (3) periods of 10–45 min with no movement are only identified as non-wear if the average temperature is below the NMT threshold and if the end of the period is within the expected awake time. Device transportation (registration of movement when the device is not worn by the child) is identified as non-wear if the average temperature of the period is below the NMT threshold.<sup>21</sup> Non-valid data will be excluded for further analysis.

Total wear time and activity counts will be processed using Matlab (Mathworks, Natick, Massachusetts, USA). To optimise wear time, parents will be offered a daily SMS message encouraging the child to wear the accelerometer.

The OMGUI V.43 software will be used to set up and configure the accelerometers. The Axivity AX3 raw acceleration data will be converted to ActiGraph counts using the methods described by Brønd *et al*.<sup>25</sup> The overall level of PA will be expressed as average counts per day. Converting Axivity raw data to ActiGraph counts will allow for comparability with typically developed children and for sub-analysis using CP-specific cut-points for estimation of time spent in sedentary, light, or moderate-to-vigorous intensity across the different gross motor function levels.<sup>22</sup>

### Cerebral Palsy Follow-Up Programme

Retrospective variables collected from the CPUP physiotherapy protocol, patient protocol, neuropaediatric protocol and orthopaedic protocol will be used to predict

the level of habitual PA. Physiotherapy assessments are reported to the database yearly for persons at GMFCS levels II and III, and biennially for persons at GMFCS level I. Assessments from the paediatricians and the orthopaedic surgeons are collected, respectively, once before the age of 5 years and based on the child's age and gross motor function.<sup>14</sup> Consequently, the retrospective CPUP data has been collected within the 38 months prior to assessment of PA level (see timeline, [figure 2](#)).

### Paediatric Quality of Life Inventory

To evaluate health-related QoL, a linguistically validated Danish version of the Paediatric Quality of Life Inventory (PedsQL) CP Module, which is specifically designed for children with CP, will be used.<sup>26</sup> It is based on the parents' reports and measures physical, emotional, social and school functioning. The construct and discriminant validity of the original version have been supported by comparing the scores from children with CP with a generic measure of the same construct from children without disability.<sup>27</sup> Satisfactory internal consistency reliability coefficients of 0.87–0.97 have been demonstrated for the PedsQL parent proxy report for children ages 8–18.<sup>28</sup>

### The Paediatric Outcomes Data Collection Instrument

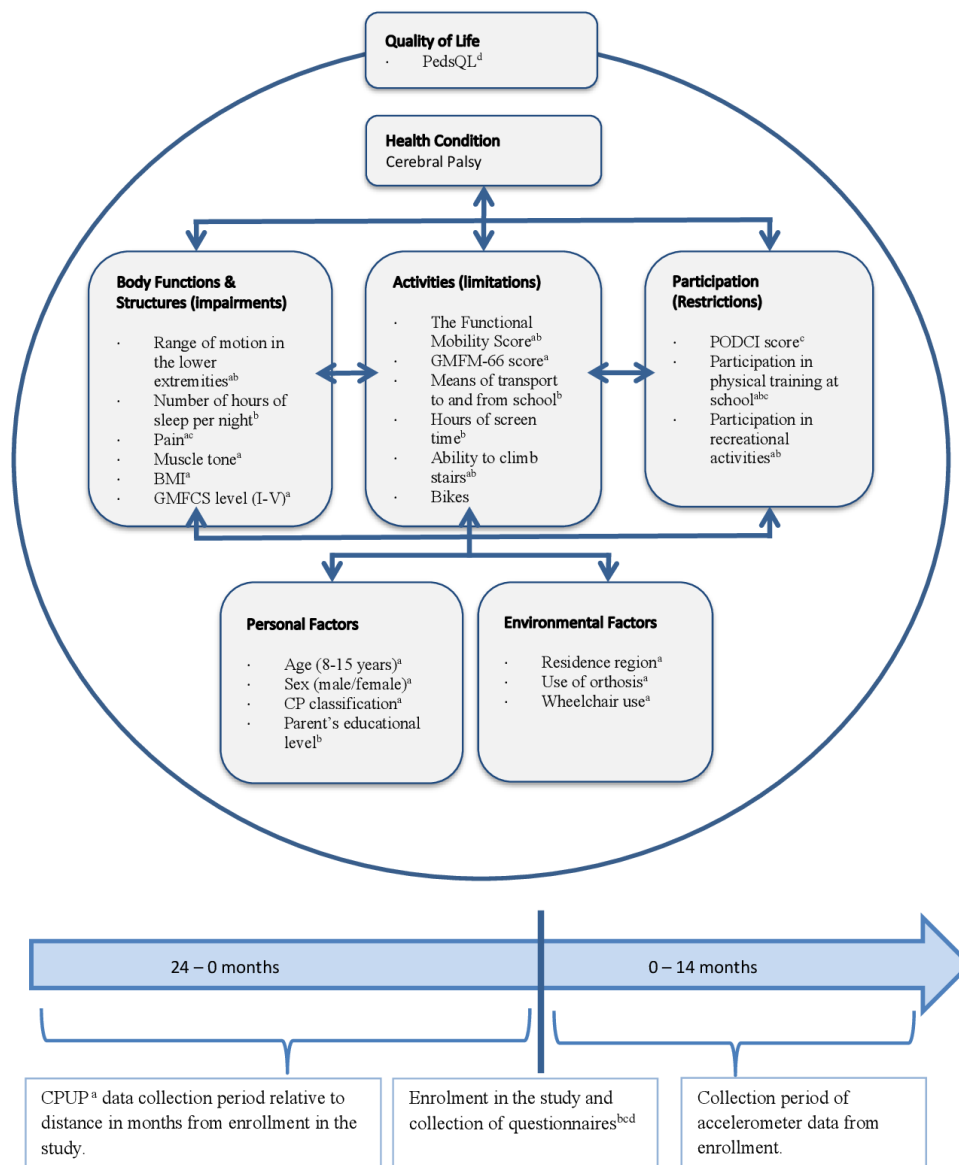
Overall health, pain and participation in normal daily activities will be assessed by a Danish version of the Paediatric Outcomes Data Collection Instrument (PODCI). Concurrent and discriminant validity have been assessed by comparing the PODCI with other measures of health and well-being, gross motor function and diagnostic subgroups in children with CP.<sup>29</sup> Moderate to good test-retest reliability with ICC values of 0.71–0.97 have been reported in children with orthopaedic or musculoskeletal disorders.<sup>30</sup>

### Supplementary questions

The following assessment will be evaluated by means of a supplementary parent-reported questionnaire: The child's average sleep and screen time on a typical weekday and weekend-day, and parent's socioeconomic status as determined by the parent (based on questionnaires used in the 'Physical activity in schools after the reform' (PHASER) study).<sup>31</sup> Visual evaluation of range of motion for the joint on the most affected side; the parent is shown a picture of a joint movement (positioned in the minimum range of motion considered acceptable according to the CPUP's physiotherapy protocol),<sup>32</sup> and is asked to evaluate whether the child's joint is capable of 'more' or 'less' movement than the depicted picture (see online supplemental appendix—Parent-evaluated range of motion in the lower extremity). Furthermore, assessment of mobility through the Functional Mobility Scale<sup>33</sup> (for more detail see [table 1](#)).

All data from the PedsQL, PODCI and supplementary questionnaires are proxy reported by a parent or caregiver.





**Figure 2** Included predictive variables sorted into components according to the modified ICF model, including data collection timeline in months. Variables derived from the following: <sup>a</sup>CPUP registry, <sup>b</sup>Parent-Reported Questionnaire, <sup>c</sup>PODCI questionnaire, <sup>d</sup>PedsQLquestionnaire. BMI, body mass index; CP, cerebral palsy; CPUP, Cerebral Palsy Follow-Up Programme; GMFCS, Gross Motor Function Classification System; ICF, International Classification of Functioning, Disability and Health; PedsQL, Paediatric Quality of Life Inventory; PODCI, Paediatric Outcomes Data Collection Instrument; PedsQL, Paediatric Quality of Life Inventory.

### Danish National Patient Register

For recruitment purposes, parents'/guardians' national security numbers will be applied for at the Danish National Patient Register, as will registry data on relevant hospital operations and procedures for the children/adolescents.

### Study size

The eligible national cohort comprises a total of approximately 1100 children and adolescents in Denmark in the age group of 8–15 years. Based on previous experience of participation in studies by this patient group, we expect an inclusion of 300–400 children.

### Statistical methods

WHO introduced the ICF in 2007 as a framework for discussing health and disability from a biopsychosocial perspective through the interaction of five components (ie, Body Functions and Structures, Activity, Participation, Personal Factors and Environmental Factors).<sup>34</sup> In 2010, QoL was integrated in a modified ICF model,<sup>35</sup> which will be used in the current study as a statistical framework. This allows separate and combined analyses for each of the six components on the prediction of habitual PA, as measured by accelerometer, and will consequently provide data-driven knowledge about using the modified ICF model as a context for habitual PA for children and adolescents with CP.

**Table 1** Predictive variables

ICF component		CPUP variables	Questionnaire variables	
Body Function & Structure	Range of motion in the lower extremities	<p><i>Continuous value:</i> Variable most associated with habitual physical activity from the following measurements (on the most affected side) measured in degrees:</p> <p>HIP</p> <ul style="list-style-type: none"> <li>▶ Abduction</li> <li>▶ Flexion</li> <li>▶ Internal rotation</li> <li>▶ External rotation</li> <li>▶ Elys test</li> <li>▶ Extension</li> </ul> <p>KNEE</p> <ul style="list-style-type: none"> <li>▶ extension (hip 90° flexion)</li> <li>▶ extension (hip 0°)</li> </ul> <p>ANKLE</p> <ul style="list-style-type: none"> <li>▶ Dorsal flexion with flexed knee</li> <li>▶ Dorsal flexion with extended knee</li> </ul>	<p>Visual evaluation of range of motion for most affected side. <i>Categorical values:</i> 'more' or 'less' than the depicted picture of the following joints (see appendix for illustrations):</p> <ul style="list-style-type: none"> <li>▶ HIP flexion KNEE extension with opposite leg extended</li> <li>▶ KNEE extension with opposite leg flexed</li> <li>▶ ANKLE flexion with extended knee</li> <li>▶ ANKLE flexion with flexed knee:               <ol style="list-style-type: none"> <li>a. Decreased range of motion</li> <li>b. Full range of motion</li> </ol> </li> </ul>	
	Number of hours of sleep per night		<p><i>Continuous value:</i></p> <ol style="list-style-type: none"> <li>1. Time in hours per day on school days.</li> <li>2. Time in hours per day in the weekend</li> </ol>	
	Pain	Categorised as Yes/No		
	Muscle tone (Modified Ashworth Scale)	<i>Categorical value:</i> The absence or presence of increased muscle tone in the most affected side of the lower extremity as evaluated on the Modified Ashworth scale.		
	BMI (body mass index)	<i>Continuous value:</i> Weight in kg / (Height (m)) <sup>2</sup>		
GMFCS level	<i>Categorical values:</i> I-III		<i>Categorical values:</i> I-III	
Activities	The Functional Mobility Score	<p><i>Categorical values</i> FMS score (1-6) for:</p> <ul style="list-style-type: none"> <li>▶ 5 metre</li> <li>▶ 50 metre</li> <li>▶ 500 metre</li> </ul>	<p><i>Categorical values</i> FMS score (1-6) for:</p> <ul style="list-style-type: none"> <li>▶ 5 metre</li> <li>▶ 50 metre</li> <li>▶ 500 metre</li> </ul>	
	GMFM-66 Score	<i>Continuous score:</i> 0–100		
	Means of transport to and from school		<p><i>Categorical values:</i></p> <ul style="list-style-type: none"> <li>▶ Walks</li> <li>▶ Bikes</li> <li>▶ Transported (eg, by car, bus, cargo bike)</li> <li>▶ Other</li> </ul>	
	Hours of screen time		<p><i>Continuous value:</i></p> <ol style="list-style-type: none"> <li>1. Time in hours per day on school days.</li> <li>2. Time in hours per day in the weekend</li> </ol>	
	Ability to climb stairs	<p><i>Categorical values:</i></p> <ol style="list-style-type: none"> <li>1. Climbs up stairs independently (Yes/No)</li> <li>2. Climbs down stairs independently (Yes/No)</li> </ol>		
	Bikes (bicycle, tricycle, running bike etc.)	<p><i>Categorical values:</i></p> <ul style="list-style-type: none"> <li>▶ Often (daily)</li> <li>▶ Sometimes (a couple of times a week)</li> <li>▶ Rarely (a couple of times a month)</li> <li>▶ Never</li> </ul>		
Participation	PODCI		<i>Continuous score:</i> 0–100	
	Participation in physical training at school	<i>Categorical values:</i> Yes/No	<i>Categorical values:</i> Yes/No	
	Participation in recreational activities	<i>Categorical values:</i> Yes/No	<p><i>Categorical values:</i></p> <ul style="list-style-type: none"> <li>▶ Swimming</li> <li>▶ Horseback riding</li> <li>▶ Soccer Handball</li> <li>▶ Dance</li> <li>▶ Strength training</li> <li>▶ Gymnastics</li> <li>▶ Basketball</li> <li>▶ Floorball</li> <li>▶ RaceRunning</li> <li>▶ Nothing Other</li> </ul>	

Continued

Table 1 Continued

ICF component	CPUP variables	Questionnaire variables
Personal Factors	Age	Age in years
	Sex	<i>Categorical values:</i> Male/Female
	CP classification	<i>Categorical values:</i> ▶ Spastic ▶ Dyskinetic ▶ Ataxic ▶ Not classified/mixed form
	Parents educational level	<i>Categorical values:</i> ▶ Primary school up to and including 6th grade ▶ Primary school 7–10th grade ▶ High school education ▶ Vocational education (eg, office and shop assistant, etc.) ▶ Short higher education (eg, market economist, police officer, etc.) ▶ Medium-term higher education (eg, teacher, educator, nurse, bachelor of political science, etc.) ▶ Long higher education (eg, master degree) ▶ PhD or research training ▶ Other education ▶ Do not know
Environmental Factors	Residence region	<i>Categorical values:</i> ▶ Region of Southern Denmark ▶ Region of Northern Denmark ▶ Central Denmark Region ▶ Region Zealand Capital ▶ Region of Denmark
	Use of orthosis	<i>Categorical values:</i> Yes/No
	Wheelchair use	<i>Categorical values:</i> ▶ Does not use ▶ Is assisted ▶ Operates independently
Quality of Life	PedsQL	<i>Continuous score:</i> 0–100

BMI, body mass index; CP, cerebral palsy; CPUP, Cerebral Palsy Follow-Up Programme; FMS, Functional Mobility Scale; GMFCS, Gross Motor Function Classification System; ICF, International Classification of Functioning, Disability and Health; PedsQL, Paediatric Quality of Life Inventory; PODCI, Paediatric Outcomes Data Collection Instrument.

The following figure operationalises the statistical framework by sorting included outcome variables according to components in the modified ICF model.

### Analysis

The identification of predictive factors of habitual PA in children and adolescents with CP between the ages of 8 and 15 years, will, as described above, be operationalised through a statistical analysis plan using the modified ICF model as a conceptual framework (figure 2). Using a predictive model, the study aims to determine the associations between the response variable and the predictive variables, with the purpose of predicting the output value for new observations given their input values.<sup>36</sup> The variable that is to be predicted (the response variable) is habitual PA, represented by accelerometer counts. Regardless of the collection time of the data, all other variables (table 1) are considered prediction variables.<sup>36</sup>

To determine which variables predict the child's level of PA, multiple linear regression analysis will be performed according to the following models:

### Primary analysis

#### Model 1

Multiple linear regression analysis between accelerometer counts (response variable) and all CPUP variables within each ICF component (predictive variables).

### Secondary analysis

#### Model 2A

Backward stepwise regression with accelerometer counts as the response variable and all included CPUP variables as predictive variables. The Akaike information criterion will be used to determine which variables to retain in the model. Resampling, as described below, will be used to address potential overfitting and to summarise the variability of selected variables.<sup>37</sup>

#### Model 2B

Multiple linear regression analysis between accelerometer counts (response variable) and all included variables as predictive variables. This model will assess the degree of predictive strength that the questionnaire variables adds to model 1.

The coefficient of determination, adjusted R-squared, will illustrate the percentage of variance in PA that is explained by the predictive variables. The higher the coefficient, the stronger the relationship. The root mean squared error of the estimate will indicate the accuracy of the predictions. Results will be presented with an alpha of 0.05 and a 95% CI.

Models will be checked using graphic inspection. Splines will be used to account for non-linear effects, and interactions will be included in the model based on relevant subject-matter knowledge. These will be specified in detail in the statistical analysis plan.

Bootstrapping will be performed to reduce the risk of overfitting the prediction model and will thus increase internal validation.<sup>38</sup> Missing data will be addressed using multiple imputation applied to each of the bootstrapped datasets.<sup>39</sup> External validation can be verified using the Swedish CPUP registry data; however, this will not be performed in the present study.

To evaluate the significance of CPUP data collection periods relative to the time in months from the measure of PA, the model will test for differences in prediction analyses between the following time periods: 0≤12 months, 13≤24 months and 25+ months (figure 2).

Analysis of non-responders and excluded participants will be performed to disclose potential selection bias.

Statistical analyses will be performed using Stata/IC 17 or later for Windows (StataCorp LLC, College Station Tx, USA).

#### Additional analyses

Several other related analyses will be reported separately. One further study will be on a subgroup of any children or adolescents who are referred for three-dimensional gait analyses as part of their individualised clinical treatment plan. Another analysis will use cut-points for sedentary, light, moderate and vigorous activity for each of the three separate GMFCS levels<sup>22</sup> and then compare sedentary behaviour and PA levels of children and adolescents with CP with those of typically developed children and adolescents. Finally, a qualitative study will be performed to explore the daily life challenges that parents describe facing in their pursuit of helping their children with CP live a physically active lifestyle. The methods and findings of this study will be reported elsewhere.

#### Adverse events

Measuring habitual PA by accelerometry is a non-invasive method commonly used in research and has no known risks or side effects, including pain or discomfort.

#### Patient and public involvement statement

A pilot study was conducted during the fall of 2019 in which five families were invited to participate and then give feedback on the questionnaires, the use of the accelerometer and the overall burden of participation. Feedback from the children and adolescents, as well as from their parents, led to minor alterations of the study design,

such as the questionnaire setup, the use of a different type of elastic belt as well as eliminating the use of an additional accelerometer worn on the thigh.

Patient user groups contributed to the assessment of the project prior to funding being granted by the Elsass Foundation and the Region of Southern Denmark.

Study results are expected to be disseminated through a national interest organisation for persons with CP (eg, articles on website, oral presentation), ensuring study results are communicated to the participants and also to a general wider patient community.

#### DISCUSSION

The present study will provide novel evidence of predictors of PA for children and adolescents with CP. Recruitment via secure digital post should increase recruitment efficiency, as eligible parties are invited to participate without dependency on healthcare attendances. Due to the wide inclusion criteria, results of this study are expected to have a high level of external validity and be generalisable to other children and adolescents with CP. To ensure the internal validity of the study, selection bias will be investigated through a non-responder analysis. A high acceptance by the treating health professionals is expected, as the majority of variables of interest are already implemented in CPUP.

The study findings may be implemented in evidence-based PA guidelines, which are currently lacking for children with CP, thus providing health professionals with a clinical instrument to help increase PA levels in children and adolescents with CP.

#### Limitations

This cohort study will be subject to some methodological limitations. Primarily, the current predictive regression analysis cannot determine causality between the predictive variables and the level of PA endured. Thus, the findings should optimally be validated in an external cohort and/or verified in randomised controlled trials. External validation of the prediction model may be achieved, for example, by using the Swedish CPUP registry data; however, this validation is not a part of the current protocol. Nevertheless, bootstrap validation will be performed to increase internal validation.<sup>38</sup>

Using registry data supports clinically relevant data on all persons in the target group; however, it also poses a risk of having data that is missing for unidentifiable reasons, which complicates the handling of missing data. In this study, missing data will be addressed using imputation of the missing values with the sample mean of the observed cases, resulting in a potential risk of biased estimates due to variance of the variable may be underestimated.

A possible 0–38 months time lag between variables collected via CPUP and the accelerometer data is a methodology limitation. As the participants are at a developmental age where physical change can be monumental,



sensitivity analysis will be performed to evaluate the potential significance of the time lag.

To allow for comparability, data on sleep time, screen time and socioeconomic status were assessed using a questionnaire developed for assessment of typically developed children and adolescents in Denmark.<sup>31</sup> Data could have been strengthened by the use of validated questionnaires.

While the WHO definition of QoL is based on an individual's perception, proxy report by parents or caregivers is often necessary in the paediatric care setting due to a child's young age and/or limited ability to self-report.<sup>40</sup> Although studies have shown that children and adolescents above the age of 5 are capable of self-reporting perceived QoL independently,<sup>41</sup> this study will use proxy evaluation due to the diverse cognitive abilities in the target group. Allowing for differentiated evaluation (proxy reported or self-reported) would complicate comparability.

Although the study aims to cover a broad aspect of ICF components, important personal and environmental factors such as self-efficacy, social support, motivation and physical access are not included in the analysis.

While children at GMFCS IV may walk assisted as a means of ambulation over short distances, or participate in active propulsion, neither level IV or V are included in this study as the use of wheelchairs complicate valid measurement of PA using accelerometer. Consequently, results of this study will not be applicable to children at a GMFCS level IV–V and thus hinders external validity.

Using tape as a means of mounting the accelerometers could potentially ensure slightly better data quality and possibly better wear compliance compared with using elastic bands.<sup>42</sup> However, placement of the accelerometer with tape requires professional assistance, thus making the use of elastic belts a far more feasible solution. Additionally, elastic belts have been reported to be more comfortable for the user.

Using only one accelerometer instead of two limits the possibility of differentiating activity types.<sup>43</sup> Furthermore, a hip worn accelerometer may exclude capturing upper-limb activities, possibly resulting in an underestimation of PA levels. However, this study will only be using one accelerometer to ensure better wear compliance among the children and adolescents.

Recruitment of participants for this study will take place during the COVID-19 pandemic. To account for the possible impact this may have on the study, parents will be asked to evaluate the degree to which their child's PA level is affected by COVID-19 on a five-point Likert scale ranging from 'He/she is a lot less physically active now than before COVID-19' to 'He/she is a lot more physically active now than before COVID-19.' Furthermore, accelerometer data are only to be collected on days that represent everyday life, that is, not quarantine days, holidays or sick days.

## CONCLUSION

The present protocol outlines a research project that will investigate predictors of habitual PA in children and adolescents with CP with the perspective of optimising PA levels and associated overall health, activities of daily living and QoL.

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