

## Research Article

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# The effect of breaking sitting time with physical activity breaks on cognitive performance in young people with cerebral palsy: an exposure response cross-over feasibility design

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### Abstract

**Objectives:** To assess the feasibility of methods and estimate the potential effect of interrupting sedentary behaviour, with intermittent or continuous physical activity breaks, on cognitive performance in young people with Cerebral Palsy.

**Methods:** A randomised three-arm exposure response cross-over design with process evaluation. Participants were recruited throughout the Thames Valley, UK between 01/11/2018 to 31/03/2020. The three 2 h activity exposure visits included: (i) sitting only (controls), (ii) sitting plus 20 min of moderate-to-vigorous activity burst, or (iii) 4×5 min of

moderate-to-vigorous activity bursts, during a 2.5 h sedentary session. Measures of feasibility were sought. Cognitive performance outcomes (using the Eriksen Flanker task and Forward and Backward Digit Span) were delivered before and after the 2 h testing period.

**Results:** 36 participants were randomised (age 13.2±2.7, Gross-Motor Functional Classification System 1–3). Study retention was 83 % across all three interventions and overall missing data for measures was 4 %. A small intervention effect was found in reaction time in the 4×5 min physical activity exposure session compared to the sedentary control condition (0.42; 95 % CI 0.40 to 0.79). There were two research-related minor adverse effects, an allergic reaction to the FreeStyle Libre and feeling faint and vomiting after consumption of glucose solution. Both events were resolved and participants continued with the study.

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**Conclusions:** The study design and intervention implementing short bursts of physical activity was feasible and indicated a potential effect on reaction time as a measure of cognitive performance in young people with cerebral palsy.

**Keywords:** cerebral palsy; physical activity; cognitive performance; child; adolescent

**Trial Registration:** ISRCTN84098935

## Introduction

Moderate to vigorous intensity physical activity is known to acutely benefit executive performance (EP) [1–3] and improve academic performance in young people [2, 4] with effects suggested to persist anywhere from minutes to several hours post-activity [5, 6]. Executive functions (EF) including inhibitory control, working memory and set shifting [7–9] are important for academic performance [6]. Young people with Cerebral Palsy (YPwCP) are more sedentary [10–13] and more commonly have deficits in executive functioning, including sustained and divided attention, short-term memory, inhibition, and set shifting, than their typically developing age-matched peers [14, 15].

When considering the optimal physical activity dose or mode of interventions to improve cognition and academic performance, there are a number of systematic reviews in neurotypical young people suggesting that moderate to vigorous intensity activity is effective, but currently there are no clear guidelines. A recent systematic review investigating interventions for cognitive functioning in children and adults with cerebral palsy (CP) [16] found 28 studies, of which nine were randomized controlled trials (RCTs). The evidence supports multi-modal and physical interventions to improve general cognitive functioning, with cognitive interventions alone improving working memory. However, the included RCTs were of a low quality and did not take account of age, sex or clinical heterogeneity [16].

A recent longitudinal 12-week exercise programme studying 60 children with left-side cerebral palsy and emotional and behavioural dysregulation, found that aerobic exercise has a promising impact on inhibitory control of executive function in these children with left-sided hemiplegic cerebral palsy [17]. This is interesting as it supports that children with deficits may benefit more. However, studies exploring the dose or mode of exercise are limited in YPwCP, with the only evidence to date supporting 15 min of moderate-intensity activity to benefit attention [18].

While YPwCP may gain cognitive [19] and physical benefits from participating in physical activity [20–24], current

barriers to achieving a physically active lifestyle in YPwCP are significant [25–27]. At school age, specific interventions to promote academic skills and physical health in children with cerebral palsy could be a major goal [28]. Aerobic training is especially important for those with CP who tend to have low cardiorespiratory fitness and a high prevalence of cardiac disease, yet evidence is limited on aerobic training effects in this population [26]. Importantly, despite the relatively low prevalence of overweight/obesity in the group tested, there was a relatively high proportion of children with CP who had elevated blood pressure values. In a recent review of children with disabilities, observational studies described sedentary behaviour patterns in 29 out of 36 studies, of which 22 were studies in children with cerebral palsy. However, few studies (n=3) were conducted to evaluate interventions for decreasing sedentary behaviour; and currently existing evidence does not support the effectiveness of strategies to reduce sedentary behaviour in children with physical disabilities.

Considering the evidence, we propose that brief moderate to vigorous intensity activity breaks during the school day, as well as benefitting fitness and health, will have the potential to improve attention and cognitive performance in YPwCP. When considering the dose, in line with evidence from a review of classroom activity interventions, we propose that short regular moderate to vigorous intensity breaks may benefit attentional control more than a single longer dose of physical activity [29]. The results of this meta-analysis showed that classroom-based physical activity breaks to reduce sedentary time had a positive effect on improving on-task and reducing off-task classroom behaviour, while also leading to improvements in academic achievement [29]. Here, we set out to determine the feasibility and potential extent of the immediate and short-term effects of interrupting sitting with two different lengths of time and brief moderate to vigorous intensity activity breaks on physical and cognitive performance in YPwCP. A graphical representation of the study is shown in Figure 1.

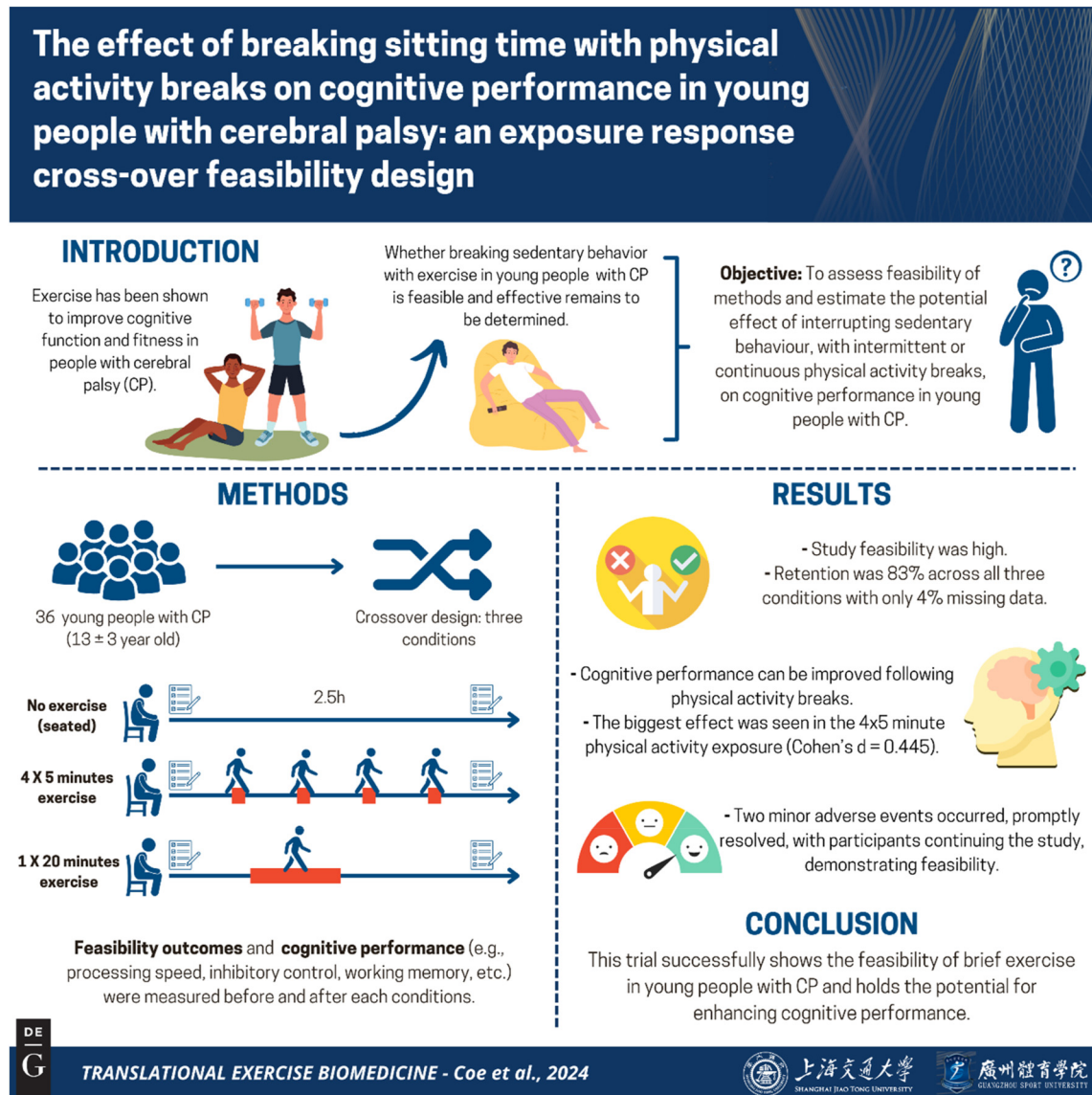
## Methods

### Design

This was a non-blinded three-armed exposure response cross-over trial to assess feasibility and effect potential. The trial received governance and ethical approvals (IRAS ID: 251813; REC: 18/SW/0200), was registered (ISRCTN84098935) and conducted in accordance with the Declaration of Helsinki (2013).

### Recruitment

Recruitment took place from 01/11/2018 until 31/03/2020 in the Thames Valley, UK. Potential participants were identified by the Children's



**Figure 1:** Graphical representation of the study. Keys points: (1) qualitative analysis of exit interviews revealed positive and constructive feedback from both children and families further supporting feasibility; (2) potential benefits for cognitive performance were found at the end of sessions that included physical activity breaks, the biggest effect in the 4x5 min physical activity exposure which achieved a small effect size (Cohen's  $d = 0.445$ , 95% CI 0.079 to 0.817). (3) Variability in cognitive performance responses to different physical activity exposures, is an important finding supporting the need for further trials and a possible need for individual tailoring of physical activity.

Community Physiotherapy Service, Oxford Health NHS Foundation Trust, paediatric clinics at Oxford University Hospitals and Oxford Health Trusts and at John Chilton School a special/adapted school (Ealing, UK).

### Sample size

As this was a feasibility study, no formal sample size calculation was performed. Instead, data from previous research estimates possible effect sizes of [0.1–1.87] on EFs from standing moderate to vigorous activity (MVA) interventions. Assuming 20% attrition, 36 YPwCP would allow a sample of 30 YPwCP. Considering a prevalence of 0.2% of YPwCP

(~250 in the stated age range in Oxfordshire Community Paediatric Physiotherapy Team caseload in special and mainstream schools) and a recruitment period of 14 months, it was assumed 36 YPwCP could be recruited and would be adequate to simultaneously address feasibility questions.

### Setting

The study took place at Oxford Brookes University, Oxford, UK and the John Chilton School, Ealing, UK. Session procedures and equipment were standardised across sites and conducted by the same researchers.

## Eligibility

Inclusion criteria: A diagnosis with Cerebral Palsy; aged between 9 and 18 years; a Gross Motor Function Classification System (GMFCS) level I to III; able to participate safely in assessments and brief interrupted sitting moderate to vigorous activity (with or without support). Exclusion criteria: type 1 and type 2 diabetes; uncontrolled epilepsy/seizures (stable epilepsy/on medication >12 weeks); surgery in previous 6 months; botulinum toxin treatment in the previous 6 weeks; serial casting in previous 3 months (or planned); contraindications to physical training; those who are considered too cognitively impaired to participate in the trial as determined by referring clinicians; children known to have spinal instability or other spinal problems that would prevent them from participating safely; children on any form of steroids, anti-anxiety/depression drugs, birth control, beta-blockers, statin, adrenaline, HIV or hepatitis C medications.

## Baseline measures: questionnaires

At baseline, information on participant demographics (age, height, weight, body composition), health history and condition severity were obtained. A trained physiotherapist assessed participant Communication Function Classification System level (CFCS) and Manual Ability Classification System level (MACS). For a full list of baseline measures, see Supplementary 1 [30–33].

## Randomisation

At baseline, participants were allocated the next available study number by the assessor. The study number related to a computer-generated randomisation list that randomised individuals (allocation ratio 1:1:1). The randomisation list was minimised to balance order for age and GMFCS level (1–2, low; 3, high). The list was held by the researcher JC who informed those supporting the intervention of group allocation.

## Allocation

At each session, the assessor allocated the participant to one of the following exposures according to the randomisation.

- (1) Interrupted sitting using four, 5 min brief moderate to vigorous intensity physical activity at every 30 min interval (4×5 min)
- (2) Interrupted sitting using a 20 min moderate to vigorous intensity physical activity (20 min)
- (3) Uninterrupted sitting (control)

## Randomisation

At the John Chilton School site, a protocol deviation of the randomisation procedure occurred, due to the school schedule. To ensure the testing sessions did not disrupt the children's timetables it was necessary to carry out the same exposure on children in the same timetabled sessions. This necessitated the exposure allocation to be pragmatically assigned for seven participants.

## Exposure sessions

Each session took approximately 2.5 h to complete and took place in the morning before 11 am due to fasting requirements (fasting for 10 h before the session, except for water). On arrival, blood pressure and resting heart rate (HR) were taken, followed by a Physical Activity Readiness Questionnaire (PAR-Q). Participants consumed a glucose solution (Rapilose®OGTT Solution, Penlan Healthcare), of which the amount was individualised according to body weight (1.75 g/kg). Glucose tolerance will be reported elsewhere. The interrupted sitting 4×5 min exposure consisted of 5 min of moderate to vigorous intensity physical activity on an upright cycle ergometer every 30 min timed from the start of the oral glucose tolerance test (OGTT). The 20 min exposure consisted of a single 20 min bout of moderate to vigorous intensity physical activity at the 40 min time point on an upright cycle ergometer from the start of consuming glucose solution. For both exposures, moderate to vigorous intensity activity was set at 50–85 %, age-predicted maximal HR and activity load was kept as similar as possible between both activity interventions for participants in order to maintain HR in the appropriate zone. During the MVA, HR was monitored using a chest strap (Polar Heart Rate Monitor, Finland) and the rate of perceived exertion (RPE) for legs and breathing was recorded following a standard methodology and using the CALER scale [34]. In between the moderate to vigorous intensity activity participants were free to engage in interactive sedentary activities, including age-appropriate laptop-based games, basic word search, colouring and videos. During the uninterrupted sitting control exposure, participants remained sedentary but were able to engage in interactive sedentary activities as for the moderate to vigorous intensity physical activity sessions. There was at least a three-day washout period between intervention sessions.

## Feasibility outcomes

Feasibility was assessed as a primary aim, and was quantified by the recruitment rate, randomisation procedure and participant acceptance of randomisation, adherence to the protocol and loss to follow-up, safety and process. We documented adverse events (AEs) and the duration of participation and dropouts were recorded. Appropriateness of data collection methods was determined through the completion of questionnaires and missing data, and through the process evaluation.

## Secondary outcome measures

Cognitive tests were performed, including the modified Eriksen Flanker task [35] measuring processing speed and inhibitory control, and the WISC Forward and Backward Digit Span measuring attention and working memory [36]. During the modified Flanker test, participants were shown five blue fish against a white background. They were asked to respond to the directionality of the middle fish, consisting of a central picture (target stimulus) surrounded by two pictures on each side of it (flankers). Outcomes were mean reaction time (RT; ms) on correct trials and percentage of correct responses. The Digit Span test required participants to repeat a string of numbers, increasing by one number each time, both forward and then backward. The outcome was the total lines (of numbers) correct. These tests were performed directly at the start

and end of each exposure session. See Supplementary 1 for further details of cognitive tests.

### Process evaluation

After the final exposure session, participants and parents/carers completed a process evaluation questionnaire. Opinions on session content practicality and acceptability were asked. The researcher asked the young people the questions, however, the parents/carers were also offered the option of completing the questionnaire with their child at home and returning it to the researchers after completion. Parents/carers completed the questionnaire themselves, either at the testing session or at home in their own time.

### Analysis

Feasibility for completeness of outcome measures was *a priori* set at 80 % criterion for success. Retention was measured by the proportion of participants who were lost to follow-up. Successful adherence to the study was defined as at least two out of three exposures completed. For intervention fidelity to the prescribed moderate to vigorous activity intensity, measured using HR, at least 80 % of the activity time needed to be achieved within heart rate between 50 and 85 % of maximum heart rate during each intervention session. For cognitive tests, two factors, Time (before and after) and Exposure (20 min, 4×5 min and control) were considered. CFCS level was used as a covariate. A type 3 fixed effects Linear Mixed Model was used to estimate the effect of each exposure on the cognitive outcomes. We tested the fixed effect of Time, Exposure and Time by Exposure interaction. Outcome variables and errors met assumptions of normality. Statistically significant interaction effects were followed with pairwise comparisons using Tukey–Kramer post hoc for each Exposure pair, separately for outcomes measured before and after the intervention/control sessions. For each pairwise comparison, effect sizes and confidence intervals were calculated using Cohen's *d*. Data were analysed using SAS/STAT 14.3. Statistical significance was defined as an alpha level of 0.05. Qualitative analysis of the process evaluation data was analysed thematically and by sentiment using a thematic analysis approach via QSR NVivo12 Plus® software.

### Feasibility

85 people were identified by recruiting clinicians, 47 declined to take part and one was ineligible (see Figure 2). Thirty-seven individuals were invited to the baseline assessment; one did not attend and 36 completed the baseline and were randomised. Four were lost to follow-up before the first exposure intervention (becoming unavailable ( $n=3$ ), an unplanned medical procedure ( $n=1$ )). 84 % of participants (32/36) completed the trial, 89 % attended two out of three visits, and 83 % attended all three. Moreover, participants in the 20 min and 4×5 min exercise burst exposure groups maintained their previously determined heart rate level (50–85 % of maximum) during 87 % and 85 % of the total exercise exposure time, respectively.

All participants answered all questionnaires at baseline. Missing data for the cognition outcome measures was 4 %. Missing data for the process evaluations was 48 %: 35 % missing for children and 62 % missing for adults/carers. There were three AEs during the trial of which two were related to the trial per se: (1) an allergic reaction to the Free-Style Libre, used to measure blood glucose (rare but reported

previously) [37], (2) feeling faint and vomiting after consumption of glucose solution. Both events were resolved and participants continued with the study. There was one adverse event unrelated to the trial. A participant had had seizures between the intervention visits, and he/she was investigated and treated by the physician. The participant discontinued the trial, however. Demographics and clinical measures are shown in Table 1.

## Results

The recruitment target ( $n=36$ ) was achieved between November 2018 and March 2020. Figure 2 shows the recruitment flow.

### Processing speed and inhibitory control

Time showed that the mean overall RT significantly decreased for all exposures from before to after the intervention  $F(1, 118)=4.32, p=0.04$  with a small effect (Cohen's  $d=0.32, 95\% \text{ CI } 0.02 \text{ to } 0.62$ , Table 2). There was a significant effect of Exposure on the overall RT,  $F(2, 98.9)=3.12, p=0.049$ . Post hoc comparison, Tukey–Kramer adjusted, showed an estimated difference of 46.36 with borderline significance between 20 min and 4×5 min with  $p=0.0517$ , in favour of the 4×5 min exposure and a small effect size (Cohen's  $d=0.445, 95\% \text{ CI } 0.079 \text{ to } 0.817$ ). Flanker correct RT (ms), reflecting inhibitory control, significantly decreased for all exposures from before to after the intervention  $F(1, 139)=4.48, p=0.04$ , with a small effect (Cohen's  $d=0.32, 95\% \text{ CI } 0.02–0.63$ ). There was no significant effect on Exposure. The effect of exposure on the incongruent RT was significant  $F(2, 1.37)=3.36, p=0.04$ . Post hoc comparison, Tukey–Kramer adjusted, showed an estimated difference of 52.41 with borderline significance between 20 min and 4×5 min, adjusted  $p=0.06$ , in favour of the 4×5 min exposure, with a small effect size (Cohen's  $d=0.435, 95\% \text{ CI } 0.63 \text{ to } 0.81$ ). A small effect was also found between the 4×5 min and the control exposures (Cohen's  $d=0.42, 95\% \text{ CI } 0.40 \text{ to } 0.79$ ). There was no effect of Time. When adjusted for age and CFCS, there was no difference between groups at baseline (range 0.08–0.98) for processing speed and inhibitory control.

### Working memory

Digit Span did not show significance for Time or Exposure. However, a small effect size was shown for Digit Span time improving before and after all sessions (Cohen's  $d=0.42, 95\% \text{ CI } 0.10 \text{ to } 0.74$ ) for all exposures.

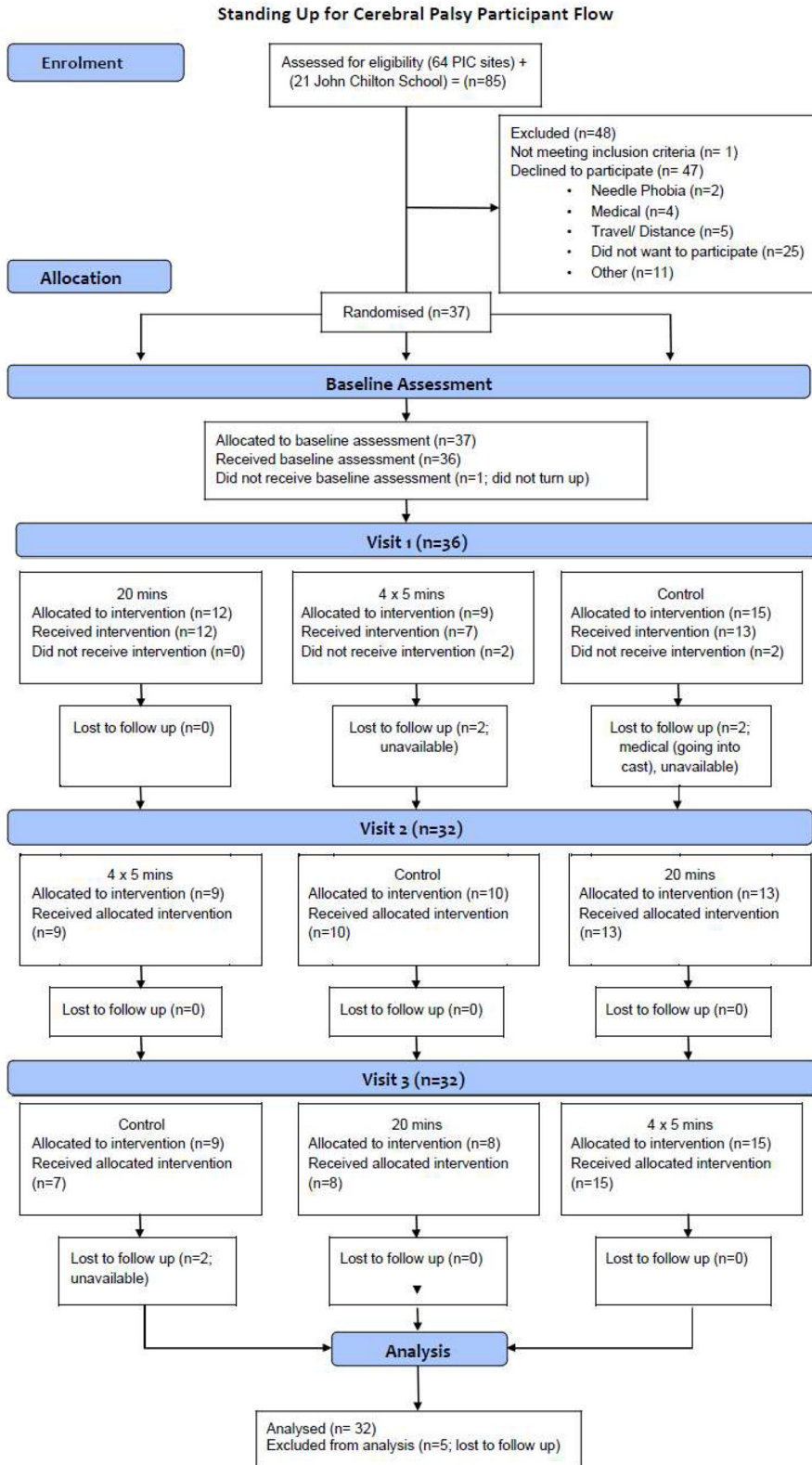


Figure 2: CONSORT flow for participants.

**Table 1:** Demographic information at baseline.

|                                | n  | Mean             |
|--------------------------------|----|------------------|
| Age                            | 32 | 13.2±2.7         |
| Gender                         | 32 | M=16/F=16        |
| Height, cm                     | 32 | 154.0±14.3       |
| Weight, kg                     | 32 | 48.0±13.9        |
| BMI, kg/m <sup>2</sup>         | 32 | 19.9±3.5         |
| GMFCS level (I–III)            | 30 | I=13/II=10/III=7 |
| CFC level (I–III)              | 29 | I=20/II=8/III=1  |
| MACS level (I–III)             | 29 | I=20/II=8/III=1  |
| <b>BP</b>                      |    |                  |
| Systolic, mmHg                 | 32 | 116.1±15.1       |
| Diastolic, mmHg                | 32 | 65.6±9.3         |
| Resting HR, bpm                | 30 | 80.2±15.9        |
| 10 m walk test, s              | 24 | 10.1±2.2         |
| <b>Grip strength, kgf</b>      |    |                  |
| Left                           | 32 | 17.2±8.6         |
| Right                          | 30 | 17.4±9.3         |
| 5× sit to stand, s             | 31 | 9.9±3.9          |
| <b>Leg strength, kgf</b>       |    |                  |
| Left                           | 31 | 71.1±41.9        |
| Right                          | 31 | 67.2±42.8        |
| VO <sub>2</sub> max, mL/kg/min | 30 | 23.7±7.7         |
| HBSC (total score)             | 30 | 2.0±1.4          |
| CHU9D (total score)            | 32 | 0.92±0.06        |
| PAQ-A (total score)            | 32 | 2.0±1.0          |

Values are presented as mean±standard deviation. (GMFCS, Gross Motor Function Classification System; CFC, Communication Function Classification System; & MACS, Manual Ability Classification System) are level of severity, with 1 being the lowest and 3 being the highest. BMI, body mass index; BP, blood pressure; HR, heart rate; VO<sub>2</sub>max, maximal aerobic power; HBSC, The Health Behaviour in School-Aged Children Dietary Habits; CHU9D, Child Health Utility 9D (Paediatric Quality of Life); PAQ-A, Modified English version of the Physical Activity Questionnaire for Adolescents. Kgf, kilogram-force.

## Process evaluation

The child evaluation included 22 out of the 36 participants who completed the questionnaire. 11 out of 22 (50 %) participants reported no challenges. There were 11/22 (50 %) negative comments including responses such as having to wake up early (1), the bike sessions were hard/long (5), and three participants did not like consuming the drink. There were seven out of 22 (32 %) negative comments around the intervention including chewing the cotton wool for saliva (1), waiting in between activity sessions on the bike (1), one participant did not like getting off and on the bike during the 4×5 session, one participant said the 20 min session was too long, hard (1), tired (1), and one person did not like wearing the HR watch. Of the neutral comments, most said it was

**Table 2:** Cognitive tests by exposure.

|                                |        | 20 min      | 4×5 min     | Control     |
|--------------------------------|--------|-------------|-------------|-------------|
| Flanker average RT             | Before | 752.4±183.0 | 709.5±156.5 | 726.7±185.2 |
|                                | After  | 706.3±142.0 | 635.7±132.2 | 708.5±185.0 |
| Flanker correct RT             | Before | 746.6±185.0 | 717.8±173.4 | 720.0±190.6 |
|                                | After  | 703.4±151.9 | 629.9±121.0 | 719.8±205.3 |
| Flanker congruent RT           | Before | 714.7±189.3 | 693.8±200.6 | 704.3±202.1 |
|                                | After  | 679.0±163.3 | 600.7±150.0 | 678.5±219.5 |
| Flanker congruent correct RT   | Before | 733.6±208.1 | 714.1±229.2 | 717.3±215.5 |
|                                | After  | 706.0±204.5 | 625.5±224.0 | 695.8±215.5 |
| Flanker incongruent RT         | Before | 787.4±225.4 | 720.4±154.1 | 749.0±201.6 |
|                                | After  | 716.4±169.9 | 659.3±151.1 | 746.4±188.8 |
| Flanker incongruent correct RT | Before | 754.5±204.6 | 718.7±217.4 | 756.4±204.3 |
|                                | After  | 743.3±193.9 | 682.4±212.4 | 766.4±204.3 |
| Flanker % correct              | Before | 80.5±26.8   | 81.5±23.0   | 80.5±25.9   |
|                                | After  | 81.2±23.0   | 79.1±23.7   | 80.1±26.1   |
| Digit Span total               | Before | 14.0±4.6    | 14.6±4.8    | 14.3±5.1    |
|                                | After  | 14.7±4.8    | 14.5±5.9    | 14.6±5.3    |

Values are means±standard deviations. FLANKER Reaction Times are measured in milliseconds (ms). Digit Span is measured by correct number of items recalled. RT, Reaction Time.

‘fine’ or they were ‘not bothered’, or they preferred one activity type to the other. There were eight (36 %) positive comments. In terms of changes to the intervention, participants indicated the possibility of using another option to the bike (4), preferred not to use the bike (2), making the intensity of the activity easier (1), and more rest in between activities (1). 9 out of 22 (41 %) participants said they would not change anything.

Respondents commented on needing more information to improve their understanding of the project and how it could potentially provide a benefit (3). Other mentions included too many sessions (1), improvement to the lab (1) and preferred sessions held locally (1). Some felt the project did not need improvement and was fine as it was (4).

All parents/carers who completed the evaluation (n=14) believed the activity was suitable for their child with no negative responses. The respondents felt both the duration (14) and frequency (12) of the sessions were just right. Two out of 14 (14 %) participants felt the frequency was too often. The majority of respondents provided positive feedback; themes included it being easy to fit into their normal routine (2), flexible scheduling around their availability (3) and it being easy on weekends and school holidays (5). Neutral or negative responses included difficulty during school times (1) or taking up a weekend (1), early mornings being a challenge (1) and parental commitment not being easy (1).

Eight (57 %) respondents felt their child would use this type of programme in schools, outpatient and rehabilitation facilities. Other comments included not sure (2) or no (5).

Over half of the respondents felt it would be easy for their child to access equipment in the future (8/14; 57%), with a few having access to a gym or having home equipment. A couple felt it was not easy without a gym membership; one suggested outside cycling would be an easy alternative.

## Discussion

The intervention was safe and well-tolerated by the participants and families who as a group showed no preference for the type of activity or delivery. However, there were personal preferences for the type of activity, delivery and physical activity dose highlighted at an individual level by young people and parents alike. We observed that brief moderate to vigorous intensity physical activity breaks (4×5 min) showed greater potential to benefit attentional control than either no physical activity or the longer duration continuous physical activity of the same intensity and dose. Considering previous observations of the impact of short bursts of physical activity on the body, and of the need to personalise physical activity for greater engagement and benefit, our findings support the potential of an individualised short-burst moderate to vigorous intensity physical activity intervention program to benefit academic performance. Overall, this exposure response was accepted and well tolerated with a high adherence rate and therefore the results from this study can be further explored in the next stage trials. Retention to the study was high overall with 89% completing at least two of the exposure sessions, and missing data was scarce. AEs were either not related or mild in nature, and two out of the three participants voluntarily continued with the trial. Related AEs were related to the assessment procedure and not the exposure.

We found that the 4×5 min indicated more potential and reduced RT compared to sedentary controls. All outcomes of Flanker were significantly different before to after for all exposures which suggested the presence of a learning effect. There were no significant effects recorded using the Digit Span test. A recent study [38] found that both low (30% HR reserve) and moderate (60% heart rate reserve) intensity running exercises improved visual reaction time and working memory in young people with intellectual disabilities. However, low-intensity running was more effective at improving visual simple reaction time compared to moderate intensity. Studies using physical activity intensities of 50% (moderate) and 85% (vigorous) on a cycle ergometer have shown that with moderate activity, both during and immediately after, anticipation timing performance increased compared to rest [18]. Different activity dosages

and intensities may impact cognition in different ways. Therefore, it is apparent that the activity duration and intensity are important when considering cognitive outcomes, although to date there is limited evidence from carefully controlled studies to direct physical activity guidelines in non-typically developing children.

Having assessed the short-term impacts of brief bouts of moderate to vigorous physical activity on cognitive performance in the current study, a trial is now warranted to assess the longer-term benefits of physical activity. An earlier study in 16 children aged 6–15 years old (8 with CP, eight typically developing) has previously reported that reaction time was significantly improved with activity, although a negative effect was found on inhibition performance with greater effects after more vigorous activity [19]. Therefore, previous studies highlight the potential of vigorous activity on some domains of cognitive functioning and a need to monitor intensity to inform better personalised prescription.

In the current study, there was no influence of brief bouts of physical activity on working memory performance. This is in contrast to other research in which performance on a word recognition memory test improved in children (aged 9–11 years) after a 20 min moderate bout of walking (20% HR max). Also, primary accuracy improved after walking compared to during walking and at rest, with overweight/obese children experiencing more benefits [39]. The differences in results between studies could be due to the high variability within our sample in performance on the outcome test used, participant demographics and sample size, and duration and intensity of activity. Future work may choose more individualised assessment and the use of minimally clinical important difference.

When considering future research, 50% (11/22) of the participants expressed no challenges during the trial and 41% (9/22) reported they would not change anything about the physical activity component of the trial. However, 23% (5/22) of participants thought that the bicycle sessions were either too long or too hard and 18% (4/22) of participants suggested using a treadmill either instead of or in addition to using the bicycle. There was no consensus in regards to the preferred activity, as some found the 20 min exposure more enjoyable and others the 4×5 min exposure. Therefore, the need to individualise the type and intensity of physical activity might need to be considered to aid adherence to future interventions. There are many factors that may influence the adherence of YPwCP to activity interventions, such as access to equipment, emotional support from family, the aid of a physiotherapist and also individual factors such as motivation, managing it with other time commitments and health outcomes [40].



Overall, the response from parents and/or carers was positive with all of those who completed the survey expressing that the activities were suitable for their child, with a vast majority also voicing that the duration and frequency of the sessions worked well. There was variation in views on optimal delivery, and the importance of individualised prescriptions was apparent. The majority of physical activity programmes for YPwCP have been shown to be more prescriptive and may not always consider preferences from the child and/or parent [40]. As such, a more individualised and holistic approach to physical activity management would be beneficial in this group. When considering the intervention, just over half of respondents said that their child would use this type of programme, whether in school, outpatient or rehabilitation services. Of the people who said they would not use this programme, one explained that they would use it if it were part of the mainstream school curriculum. Currently, there is a lack of evidence of how to best include children with disabilities including CP into mainstream school physical education, with barriers including appropriateness of equipment and consideration of the disability, and a lack of awareness and support from teachers and peers [41]. It was generally understood that early mornings were optimal due to the fasting period, and some believed that weekends were in fact preferable as they did not interfere with weekly school and work. Therefore, these factors should be considered in future trials, and any final activity program for YPwCP should take into consideration other daily commitments of both the child and parent/carer.

## Limitations

The current study used a cycle ergometer in order to more easily standardise the intervention, however in this population group this approach was not always optimal for those with higher GMFCS levels, and those with mobility impairments. Difficulties were identified particularly on the 4×5 min exposures where the participants were required to get on and off the bike multiple times. Along with the feedback in the process evaluations from the participants, we propose a more individualised approach. Working in a school environment highlighted the challenges of breaking sitting time and the potential need from the teachers to have the same approach for all classmates. This may mean that the approach is not optimal for all. However, group-based exercise intervention programmes in YPwCP have been shown to be successful.

## Conclusions

Feasibility for the trial methodology was demonstrated, with high adherence and acceptability, low AEs and positive and constructive comments from the qualitative exit interviews from both children and families. The need for cluster randomisation in future studies was highlighted by the need to deliver the same intervention within a class setting. Potential benefits of breaking up sedentary behaviour were observed, particularly with shorter breaks and therefore should receive further investigation. The use of brief bouts of moderate to vigorous physical activity intensity could show promise for improvements in cognitive performance in YPwCP alongside those established for physical functioning and could be incorporated into the school or home setting to improve academic performance, potentially improving the life quality.

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**Research ethics:** The trial received governance and ethical approvals (IRAS ID: 251813; REC: 18/SW/0200), was registered (ISRCTN84098935) and conducted in accordance with the Declaration of Helsinki (2013).

**Informed consent:** Informed consent was obtained from all individuals included in this study, or their legal guardians or wards.

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**Data availability:** The raw data can be obtained on request from the corresponding author.

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