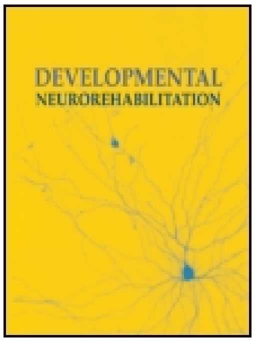


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Developmental Neurorehabilitation

ISSN: 1751-8423 (Print) 1751-8431 (Online) Journal homepage: http://www.tandfonline.com/loi/ipdr20

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**To cite this article:** Shannon Knights, Nicholas Graham, Lauren Switzer, Hamilton Hernandez, Zi Ye, Briar Findlay, Wen Yan Xie, Virginia Wright & Darcy Fehlings (2016) An innovative cycling exergame to promote cardiovascular fitness in youth with cerebral palsy, Developmental Neurorehabilitation, 19:2, 135-140, DOI: 10.3109/17518423.2014.923056

**To link to this article:** http://dx.doi.org/10.3109/17518423.2014.923056

Published online: 20 Jun 2014.

DEVELOPMENTAL NEUROREHABILITATION
ISSN: 1751-8423 (print), 1751-8431 (electronic)
Dev Neurorehabil, 2016; 19(2): 135–140

DOI: 10.3109/17518423.2014.923056
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BRIEF REPORT

# An innovative cycling exergame to promote cardiovascular fitness in youth with cerebral palsy

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**Abstract**

*Objective*: To evaluate the effects of an internet-platform exergame cycling programme on cardiovascular fitness of youth with cerebral palsy (CP). *Methods*: In this pilot prospective case series, eight youth with bilateral spastic CP, Gross Motor Functional Classification System (GMFCS) level III, completed a six-week exergame programme. Outcomes were obtained at baseline and post-intervention. The primary outcome measure was the GMFCS III-specific shuttle run test (SRT-III). Secondary outcomes included health-related quality of life (HQL) as measured by the KIDSCREEN-52 questionnaire, six-minute walk test, Wingate arm cranking test and anthropomorphic measurements. *Results*: There were significant improvements in the SRT-III ($t = -2.5$, $p = 0.04$, $d = 0.88$) post-intervention. There were no significant changes in secondary outcomes. *Conclusion*: An exergame cycling programme may lead to improvement in cardiovascular fitness in youth with CP. This study was limited by small sample size and lack of a comparison group. Future research is warranted.

**Keywords**

Cardiovascular fitness, cerebral palsy, health-related quality of life, interactive computer play, virtual reality

**History**

Received 6 March 2014
Revised 7 May 2014
Accepted 7 May 2014
Published online 19 June 2014

## Introduction

Youth with cerebral palsy (CP) are at risk for declining motor function during adolescence [1]. This decline is functionally significant for youth at Gross Motor Functional Classification System (GMFCS) [2] level III who may transition from a walker to a wheelchair as their primary form of mobility in the community. Many factors contribute to the loss of function in adolescents with GMFCS III CP, including muscle weakness, poor cardiovascular fitness and changes in body composition [1]. Cardiovascular fitness is a modifiable factor that can be enhanced through physical activity. However, adolescents with CP participate in less physical activity than their typically developing peers, and their participation often declines with age [3]. Youth with CP also have lower levels of social interaction, and this can further decrease as they grow older [4].

Exergames, a type of interactive computer play, are emerging as a novel approach to address the challenges of declining fitness and social isolation. Exergames are videogames that require physical activity and can offer opportunities for social interaction through multiplayer use. The use of in-home gaming units can eliminate accessibility barriers to participation. Commercially available exergames have been shown to improve aerobic fitness in overweight children without physical disabilities [5]. Studies have shown that youth with CP can achieve moderate levels of energy expenditure while playing exergames [6, 7]. However, there is limited knowledge about whether this translates into changes in cardiovascular fitness. One study showed improvement in a measure of cardiac fitness in youth with CP (GMFCS I and II) after a 20-week interactive computer play intervention [8]. There is limited evidence for individuals with GMFCS level III CP. Exergames have been shown to be enjoyable [6] and to increase levels of participation, motivation and satisfaction [9] in youth with CP. However, little is known about the relationship between exergames and health-related quality of life (HQL). The primary objective of this pilot study was to evaluate the effect of an exergame cycling programme on cardiovascular fitness of youth with GMFCS level III CP. We hypothesized that participation in a six-week exergame intervention would be associated with improvement. Secondary objectives were to evaluate the effects of the exergames on HQL, exercise tolerance, anaerobic power and adiposity.

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## Methods

### Participants

Participants were a voluntary convenience sample of eight children with bilateral spastic CP. Inclusion criteria were as follows: age 9–18 years; GMFCS level III; high-speed internet in the home; and ability to operate a hand-held videogame controller. Exclusion criteria were as follows: orthopedic surgery in the preceding six months and exercise-induced asthma. Eleven youths were identified through outpatient clinics at a rehabilitation hospital and consecutively approached.

### Study design

In this pilot prospective case series, participants completed a six-week home-based internet-platform exergame cycling programme. Assessments were performed at baseline and two days post-intervention. All assessments were done at the same time of day and in the same location. Approval was granted by the Holland Bloorview and Queen's University Health Science Research Ethics Boards. All participants and caregivers gave written informed consent.

### Intervention

The participants received customized recumbent bicycle units [10]. Each unit consisted of a PCGamerBike Mini (3D Innovations, Edmundston, Canada) attached to a specialized seat and connected to a Toshiba DX730 computer (Figure 1). Each unit required $2 \times 4$ feet of floor space and cost approximately $2500. Six different multiplayer exergames were designed [10]. Game avatars were powered by the participants' cycling. Hand-held videogame controllers were programmed using two functions to reduce fine motor demands. Participants wore headsets to communicate using TeamSpeak voice-over IP software, as well as armband heart rate (HR) monitors with Bluetooth technology (IMPACT Sports Technologies, San Diego, CA). Research staff monitored all game play to address technical concerns and to engage in multiplayer play if only one participant was present.

Each participant's HR and number of minutes playing the exergames were monitored. Target HR was defined as 40–60% of HR reserve, and HR reserve was calculated as [desired percentage (40–60%)$\times$(HRmax$-$HRrest)]+HRrest, where HRmax was set at 194 bpm [11] and HRrest was the participant's resting HR. Participants were asked to play for at least 30 minutes per day a minimum of three days per week and to achieve their target HR for at least 60 minutes per week. These guidelines were based on the American College of Sports Medicine (ACSM) recommendations for cardiorespiratory fitness for individuals with CP [12]. The exergames included incentives for reaching target HR, such as additional ''power-ups''. Cues on the computer screen (e.g. a heart that turned red when in the target HR zone) provided visual feedback. Games were available during specified time slots six days per week. A research assistant provided individual weekly coaching sessions to review the participants' performance, encourage them to achieve their goals and screen for adverse events.

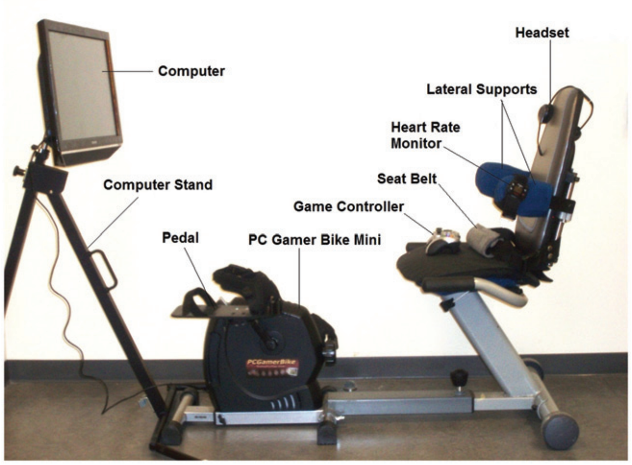


Figure 1. The exergame cycling unit.

Halfway through the intervention, several participants were playing for much longer than the recommended playtime. Due to concern about possible over-exertion or injury, limits were introduced to restrict the amount of playtime. Participants were allowed to play for a maximum of 60 minutes per day, including a maximum of 30 minutes per day above target HR. The games were unavailable for three days in week four while these limits were integrated into the software.

### Primary outcome measure

Cardiovascular fitness was measured using the GMFCS level III-specific shuttle run test (SRT-III) [13]. Using their assistive devices, participants walked/ran a distance of 7.5 m at increasingly faster speeds as determined by an auditory signal. The starting speed was 1.5 km/hour with a graded increase of 0.19 km/hour per minute. Participants wore HR monitors. A peak HR of at least 180 bpm during the SRT-III is recommended as an indicator of maximal effort [13]. The test was stopped when the participant did not reach the 7.5 m marker on two consecutive paced signals, regardless of the peak HR. The highest half-level completed was recorded, with higher levels indicating better cardiovascular fitness. The SRT-III is a reliable measure of cardiorespiratory fitness in youth with GMFCS level III CP. The standard error of measurement is 0.48 levels, and the smallest detectable change is 1.32 levels [13].

### Secondary outcome measures

HQL was evaluated using the KIDSCREEN-52 questionnaire. Six relevant domains were included: ''Physical Activities and Health'', ''Feelings'', ''Mood and Emotions'', ''Self-Perception'', ''Autonomy'' and ''Peers''. Higher scores on the KIDSCREEN-52 indicate better HQL. Reliability has been established in a large cross-cultural study [14]. The six-minute walk test is a reliable measure of exercise tolerance for ambulation in the community, with a minimum detectable change of 47.4 m for children with GMFCS level III CP [15]. The Wingate arm cranking test is a reliable measure of anaerobic power for children with CP [16]. Load was determined based on each participant's height, weight and a torque factor of 0.26. Participants completed a two-minute habituation phase, followed by a 30-second maximal effort phase. Mean power was the outcome. Anthropomorphic measurements were obtained to assess adiposity. Waist circumference was measured between the iliac crests and inferior rib cage using a flexible tape measure [17]. Triceps skinfold thickness was measured at the midpoint between the acromion and olecranon using a caliper [17].

### Statistical analyses

Descriptive statistics were calculated for all outcome variables. Paired *t*-tests were performed to assess change post-intervention. A *p* value of 0.05 was set as the level of statistical significance for the primary outcome. Bonferroni corrections were applied to the secondary outcomes with an adjusted *p* value of 0.005. Cohen's *d* was used to measure effect size, and *d* values of $\geq$0.8 were considered large [18]. Correlations between the primary outcome measure, playtime and baseline characteristics were also evaluated.

## Results

### Demographic information

Three of 11 eligible youth declined participation, giving a recruitment rate of 73%. Eight youth (six males and two females; mean age 14.3; SD 2.5 years; range 9–18 years) with bilateral spastic CP classified at GMFCS level III participated. Body mass index (BMI), Manual Ability Classification System (MACS) [19] and Gross Motor Function Measure (GMFM-66) scores [20] were assessed at baseline (Table I). Mean waist circumference and triceps skinfold thickness were 83.1, SD 11.9 cm, and 27.8, SD 14.2 mm, at baseline, respectively. One participant left on a vacation after four weeks, and her post-intervention outcomes were obtained at that time. All other participants completed the six-week exergame cycling programme. One participant had mild skin breakdown from his knees rubbing together while cycling. His bicycle was modified with a pummel. There were no other adverse events.

### HR and playtime

Mean weekly playtime per participant was 202, SD 95, minutes, with 79, SD 48, minutes (39% of playtime) above target HR. Seven participants achieved the goal for mean weekly playtime and five achieved the goal for mean playtime above target HR (Table I). Mean weekly playtime and time above target HR graphed across the six weeks are shown in Figure 2. Apart from week four, the goal of 60 minutes of mean weekly playtime above target HR was exceeded each week. Percentage of total playtime at different levels of HR reserve is shown in Figure 3.

### Primary outcome

There was a significant improvement in the mean level achieved on the SRT-III, from 4.8 SD 4.6 to 6.4 SD 5.0 ($t = -2.5$, $p = 0.04$, $d = 0.88$). The mean change was 1.7 SD 1.9 levels. One participant showed no change, and the other participants showed improvement varying from 0.5 to 5 levels. There were no significant correlations between changes in SRT-III and weekly playtime, time above target HR, BMI percentile, MACS level, or GMFM-66 score ($r = -0.55$ to 0.53, $p > 0.18$). Peak HR during the SRT-III is shown in Table I. GMFM-66 scores were correlated with peak HR during the SRT-III ($r = 0.74$, $p = 0.04$).

### Secondary outcomes

There were no significant changes in secondary outcomes: six-minute walk test (mean change 3.2 SD 13.1 m, $p = 0.52$), Wingate arm cranking test (mean change 5.4 SD 10.9 watts, $p = 0.21$), KIDSCREEN-52 domains (''Feelings'' (mean change −3.2 SD 8.4 points, $p = 0.31$), ''Mood and Emotions'' (mean change 5.5 SD 11.0 points, $p = 0.20$), ''Self-Perception'' (mean change 4.6 SD 7.3 points, $p = 0.12$), ''Autonomy'' (mean change −3.7 SD 10.9 points, $p = 0.36$), ''Peers'' (mean change −1.8 SD 16.7 points, $p = 0.77$) and triceps skinfold thickness (mean change −0.5 SD 8.8 mm, $p = 0.89$). There was an increase in the ''Physical Activities and Health'' domain of the KIDSCREEN-52 with a mean change of 9.6 SD 9.6 points ($p = 0.03$), but this did not achieve the Bonferroni adjusted level of statistical significance. There was a decrease in waist circumference with a mean change of −3.9 SD 3.9 cm, but the reduction was not statistically significant ($p = 0.03$).

### Enjoyment

In rating their enjoyment of the exergames on a scale from one (lowest) to ten (highest), the participants' mean scores varied from 6.3 to 8.8 for the six games. Informal comments included: ''I haven't had this [much] fun in years'' and ''I can't wait until after school so I can play''.

## Discussion

This pilot study suggests that a six-week exergame cycling intervention is associated with improvement in a measure of cardiovascular fitness in youth with CP classified at GMFCS

Table I. Participant characteristics ($n = 8$) and results.

| Participant | Age (years) | Sex | BMI for age and sex (%ile) | MACS | GMFM-66 score (%) | Mean weekly playtime (min) | Mean weekly playtime above THR (min) | Peak HR during SRT-III at baseline | Peak HR during SRT-III post-trial | Change in SRT-III level |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 16.3 | M | 89 | 3 | 40.4 | 171.2 | 61.5 | 145 | 126 | +1 |
| 2 | 18.3 | F | 89 | 2 | 67.7 | 195.1 | 42.5 | 156 | 187 | +4.5 |
| 3 | 12.9 | M | 63 | 2 | 45.1 | 238.6 | 130.7 | 153 | 138 | +1 |
| 4 | 15.2 | F | 97 | 2 | 58.1 | 308.7 | 103.8 | 181 | 147 | +0.5 |
| 5 | 14.0 | M | 84 | 2 | 66 | 357.2 | 160.2 | 192 | 174 | +1 |
| 6 | 14.1 | M | 3 | 2 | 52.6 | 73.6 | 24.9 | 132 | 163 | +0.5 |
| 7 | 14.1 | M | 3 | 3 | 44.4 | 134.8 | 65.9 | 126 | 154 | 0 |
| 8 | 9.7 | M | 97 | 2 | 38.7 | 136.8 | 41.3 | 108 | 174 | +5 |
| Mean | 14.3 SD 2.5 | – | 65.6 SD 40.1 | – | 51.6 SD 11.3 | 202 SD 94.9 | 78.9 SD 47.9 | 149.1 SD 27.9 | 157.9 SD 20.5 | 1.7 SD 1.9 |

BMI, body mass index; MACS, manual ability classification system; GMFM, gross motor function measure; THR, target heart rate; HR, heart rate; SRT-III, shuttle run test; and SD, standard deviation.

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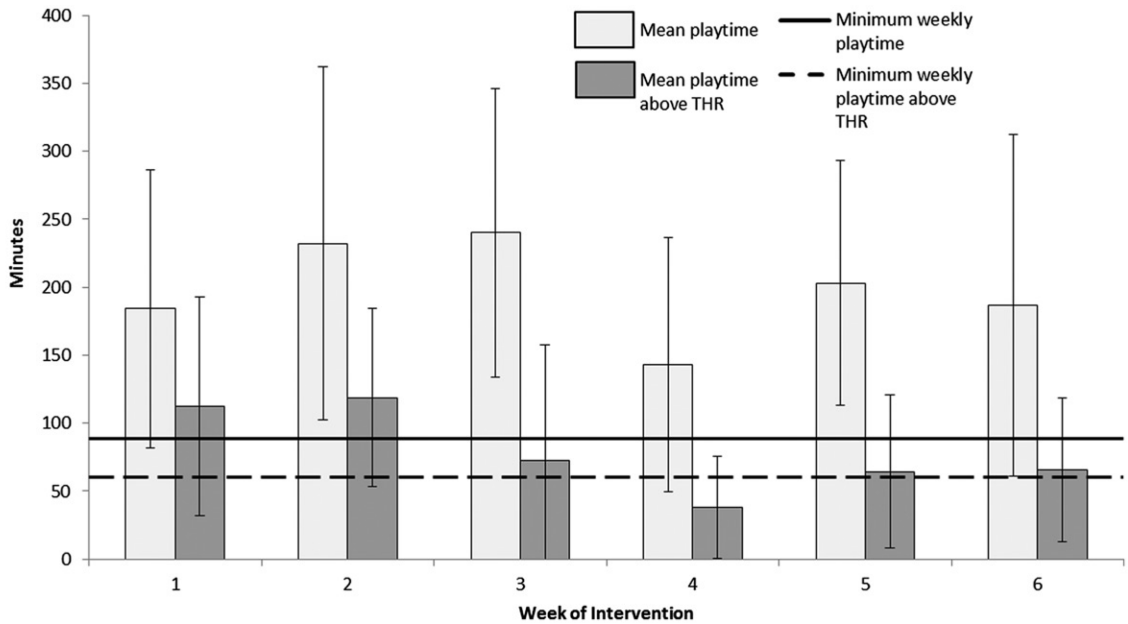


Figure 2. Mean weekly playtime and mean weekly playtime above target heart rate per participant over the six-week intervention. Error bars represent standard deviations. The horizontal lines denote the recommended minimum weekly playtime of 90 minutes and the recommended minimum weekly playtime above target heart rate of 60 minutes.

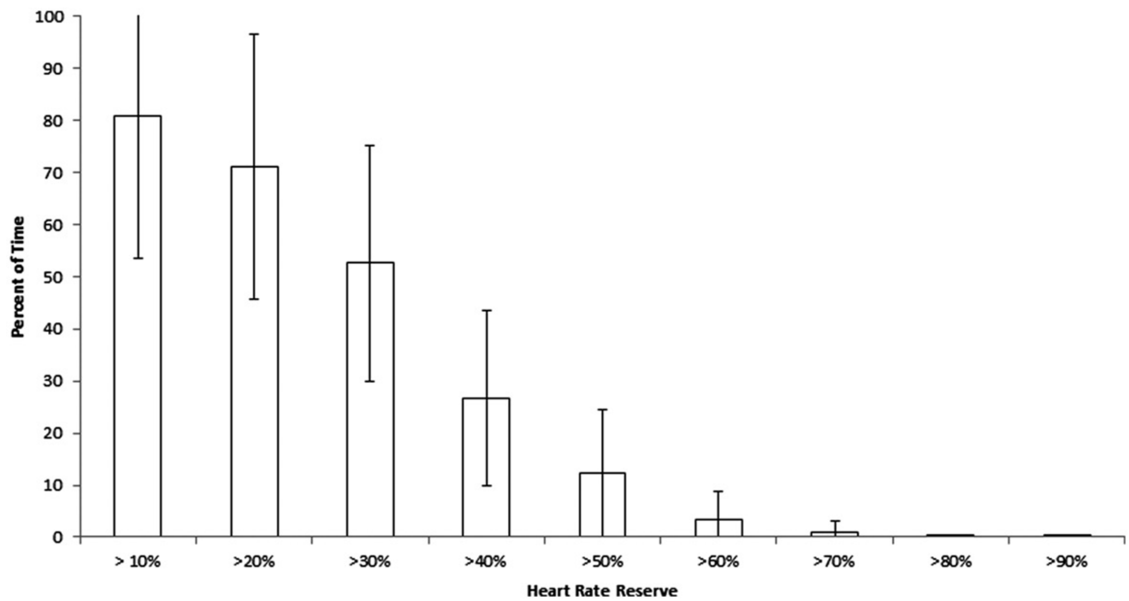


Figure 3. Percentage of total playtime at different levels of heart rate reserve. Error bars represent standard deviations.



level III. Exergames may be an important component to add to the rehabilitation tool kit. They have the potential to improve fitness in a manner that is fun and enhances adherence.

The mean level achieved on the SRT-III increased by 1.7 levels, which represents a large effect size and exceeds the minimum detectable change of 1.32 levels. While this change is clinically significant at a group level, there was wide individual variability in changes on the SRT-III. Improvements in SRT-III were not explained by weekly playtime, time above target HR, BMI percentile, MACS level or GMFM-66 score. It is notable that improvement was observed after a short six-week intervention.

Many of the participants did not achieve a peak HR of 180 bpm during the SRT-III, as recommended in the test protocol [13]. Peak HR during the SRT-III was highly correlated with GMFM-66 scores, suggesting that the SRT-III performance of some participants may have been limited more by gross motor ability and less by cardiovascular exertion. Given these limitations in peak HR, improvement in SRT-III performance could be interpreted as either an improvement in cardiovascular fitness or better exercise tolerance. The SRT-III has excellent test–retest reliability with intra-class correlation coefficients of 0.98 [13]; therefore, it is unlikely that the change in this measure was due to a learning effect. Inclusion of additional objective measures of cardiovascular fitness such as maximal oxygen consumption will be helpful in future research.

On average, participants exceeded the goals for weekly playtime and target HR. To improve aerobic capacity, the ACSM recommends exercise at 40–85% of HR reserve for 20–40 minutes three to five days per week, corresponding to moderate to vigorous intensity exercise [21]. Our exergame system allowed participants to achieve the recommended elevations in HR. This level of activity has been shown to promote cardiovascular fitness when sustained over time [21]. Most of the participants' time above target HR occurred between 40 and 60% of HR reserve, with very little playtime above 60% HR reserve (Figure 3). The exergame intervention yielded moderate intensity aerobic activity but minimal vigorous intensity activity.

This study shows that exergames can be successfully and safely adapted for use in youth with GMFCS level III CP. Since youth with GMFCS III CP have more difficulty playing commercial exergames that require prolonged standing or balance, recumbent cycling-based exergames may be better suited to this group. Previous studies of exergames have shown a substantial decline in interest over time [22, 23]. In contrast, our study showed sustained participation over the six weeks, which may be explained by several factors. Individual games were introduced at different times during the intervention to maintain interest. The youth were engaged in social interaction through multiplayer game play. Group play has been shown to increase motivation to participate in exergames [24]. Participants also had the support of an exercise coach who contacted them weekly to encourage them to achieve their playtime and HR targets. This personal contact may have increased their motivation to participate. During weeks four to six, participants were asked to limit their total playtime due to concerns about possible over-exertion. This likely contributed to the lower mean playtime in week four when the limits were being modified, and the games were unavailable for three days (Figure 2).

There were no significant changes in HQL. There was an improvement in the ''Physical Activities and Health'' domain score of the KIDSCREEN-52. However, this did not reach statistical significance, due to the small sample size of this pilot study. Other research has shown a relationship between fitness and HQL in individuals with CP [25]. The relationship between physical activity and psychosocial functioning is less well understood. One study of a stationary cycling intervention for youth with CP showed a positive influence on emotional functioning [26]. Despite reported enjoyment and opportunities for social interaction, our study did not yield significant changes in domains related to emotional or social HQL.

There were no significant changes in other secondary outcomes. There was a mean decrease in waist circumference of 3.9 cm that did not reach statistical significance, likely due to small sample size. Waist circumference is associated with obesity in children [17], suggesting that exergames may help manage weight gain. The six-minute walk test, a measure of exercise tolerance, did not change. This outcome has been studied in other exergames with both positive [27] and negative [8] results. Anaerobic power, measured by the Wingate test, did not improve. In future, adding anaerobic training to the programme may help elicit changes in this measure.

In conclusion, this pilot study demonstrates potential for improvement in cardiovascular fitness in youth with GMFCS level III CP following a six-week exergame cycling programme. Limitations of the study include the lack of a comparison group and a small sample size. Future research involving youth with other types of disability and typically developing peers will be undertaken to increase the generalizability of the exergame programme.

## Acknowledgments

The authors thank the participants who donated their time to participate in this study.

## Declaration of interest

This study was jointly funded by NeuroDevNet and GRAND, Networks of Centres of Excellence of Canada. The funders had no involvement in study design, data collection, data analysis, manuscript preparation and/or publication decisions.

## References

1. Bartlett DJ, Hanna SE, Avery L, Stevenson RD, Galuppi B. Correlates of decline in gross motor capacity in adolescents with cerebral palsy in Gross Motor Function Classification System levels III to V: An exploratory study. Developmental Medicine and Child Neurology 2010;52:e155–e160.
2. Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Developmental Medicine and Child Neurology 1997;39:214–223.
3. Maher CA, Williams MT, Olds T, Lane AE. Physical and sedentary activity in adolescents with cerebral palsy. Developmental Medicine and Child Neurology 2007;49:450–457.
4. Palisano RJ, Kang LJ, Chiarello LA, Orlin M, Oeffinger D, Maggs J. Social and community participation of children and youth with cerebral palsy is associated with age and gross motor function classification. Physical Therapy 2009;89:1304–1314.
5. Murphy EC, Carson L, Neal W, Baylis C, Donley D, Yeater R. Effects of an exercise intervention using Dance Dance Revolution on endothelial function and other risk factors in overweight children. International Journal of Pediatric Obesity 2009;4: 205–214.
6. Howcroft J, Klejman S, Fehlings D, Wright V, Zabjek K, Andrysek J, Biddiss E. Active video game play in children with cerebral palsy: Potential for physical activity promotion and rehabilitation therapies. Archives of Physical Medicine and Rehabilitation 2012;93:1448–1456.
7. Sandlund M, Waterworth EL, Hager C. Using motion interactive games to promote physical activity and enhance motor performance in children with cerebral palsy. Developmental Neurorehabilitation 2011;14:15–21.
8. Bilde PE, Kliim-Due M, Rasmussen B, Petersen LZ, Petersen TH, Nielsen JB. Individualized, home-based interactive training of cerebral palsy children delivered through the Internet. BMC Neurology 2011;11:32.
9. Sharan D, Ajeesh PS, Rameshkumar R, Mathankumar M, Paulina RJ, Manjula M. Virtual reality based therapy for post operative rehabilitation of children with cerebral palsy. Work 2012;41: 3612–3615.
10. Hernandez H, Ye Z, Graham N, Fehlings D, Switzer L. Designing action-based exergames for children with cerebral palsy. Proceedings from ACM SIGCHI Conference on Human Factors in Computing Systems. New York, USA: Association for Computing Machinery; 2013. pp 1261–1270.

11. Verschuren O, Maltais DB, Takken T. The 220-age equation does not predict maximum heart rate in children and adolescents. Developmental Medicine and Child Neurology 2011;53:861–864.
12. American College of Sports Medicine [Internet]. Health-related fitness for children and adults with cerebral palsy. Indianapolis, IN; 2007. Available from: http://www.acsm.org/docs/current-comments/health-relatedfitnessforcawithcp.pdf [last accessed 1 July 2013].
13. Verschuren O, Bosma L, Takken T. Reliability of a shuttle run test for children with cerebral palsy who are classified at Gross Motor Function Classification System level III. Developmental Medicine and Child Neurology 2011;53:470–472.
14. Ravens-Sieberer U, Gosch A, Rajmil L, Erhart M, Bruil J, Power M, Duer W, Auquier P, Cloetta B, Czemy L, et al. The KIDSCREEN-52 quality of life measure for children and adolescents: Psychometric results from a cross-cultural survey in 13 European countries. Value in Health 2008;11:645–658.
15. Thompson P, Beath T, Bell J, Jacobson G, Phair T, Salbach NM, Wright FV. Test-retest reliability of the 10-metre fast walk test and 6-minute walk test in ambulatory school-aged children with cerebral palsy. Developmental Medicine and Child Neurology 2008;50:370–376.
16. van den Berg-Emons RJ, van Baak MA, de Barbanson DC, Speth L, Saris WH. Reliability of tests to determine peak aerobic power, anaerobic power and isokinetic muscle strength in children with spastic cerebral palsy. Developmental Medicine and Child Neurology 1996;38:1117–1125.
17. Maffeis C, Grezzani A, Pietrobelli A, Provera S, Tato L. Does waist circumference predict fat gain in children? International Journal of Obesity and Related Metabolic Disorders 2001;25: 978–983.
18. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates; 1988.
19. Eliasson AC, Krumlinde-Sundholm L, Rosblad B, Beckung E, Arner M, Ohrvall AM, Rosenbaum P. The Manual Ability Classification System (MACS) for children with cerebral palsy: Scale development and evidence of validity and reliability. Developmental Medicine and Child Neurology 2006; 48:549–554.
20. Russell DJ, Avery LM, Rosenbaum PL, Raina PS, Walter SD, Palisano RJ. Improved scaling of the gross motor function measure for children with cerebral palsy: Evidence of reliability and validity. Physical therapy 2000;80:873–885.
21. Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett Jr DR, Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS. Compendium of physical activities: A second update of codes and MET values. Medicine and Science in Sports and Exercise 2011;43:1575–1581.
22. Owens SG, Garner JC 3rd, Loftin JM, van Blerk N, Ermin K. Changes in physical activity and fitness after 3 months of home Wii Fit use. Journal of Strength and Conditioning Research 2011;25: 3191–3197.
23. Sun H. Exergaming impact on physical activity and interest in elementary school children. Research Quarterly for Exercise and Sport 2012;83:212–220.
24. Chin APMJ, Jacobs WM, Vaessen EP, Titze S, van Mechelen W. The motivation of children to play an active video game. Journal of Science and Medicine in Sport 2008;11:163–166.
25. Thorpe D. The role of fitness in health and disease: Status of adults with cerebral palsy. Developmental Medicine and Child Neurology 2009;51(Suppl 4):52–58.
26. Demuth SK, Knutson LM, Fowler EG. The PEDALS stationary cycling intervention and health-related quality of life in children with cerebral palsy: A randomized controlled trial. Developmental Medicine and Child Neurology 2012;54: 654–661.
27. Wu YN, Ren Y, Hwang M, Gaebler-Spira DJ, Zhang LQ. Efficacy of robotic rehabilitation of ankle impairments in children with cerebral palsy. Conference Proceedings: Annual International Conference of the IEEE Engineering in Medicine and Biology Society 2010;2010:4481–4484.