Using motion interactive games to promote physical activity and enhance motor performance in children with cerebral palsy

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Abstract

Objective: To explore the feasibility of using low-cost motion interactive games as a home-based intervention for children with cerebral palsy (CP).

Methods: Fourteen children with CP, 6-16 years practiced with the EyeToy for PlayStation2 in their homes during four weeks. Outcome measures were physical activity monitors, Movement Assessment Battery for Children-2 (mABC-2), Bruininks-Oseretsky Test of Motor Proficiency (subtest 5:6), 1 Minute Walk Test, and gaming diaries.

Results: Motivation for practice and compliance of training were high. The children's physical activity increased during the intervention and activity monitors were feasible to use although data loss may be a concern. According to mABC-2 the children's motor performance improved, but there were both floor and ceiling effects. The two additional motor tests showed only non-significant progress.

Conclusion: It is highly feasible to use motion interactive games in home rehabilitation for children with CP. Specific motor effects need to be further explored.

Introduction

The objective of the present study was to evaluate home-based training with low-cost motion interactive games in order to promote physical activity and enhance motor performance in children with cerebral palsy (CP). The study was designed as a feasibility study with focus on; 1) motivation for practice and compliance of training, 2) impact on physical activity and the feasibility of using activity monitors to assess energy expenditure during free living conditions in children with CP, and 3) impact on motor performance, and the feasibility of possible instruments to assess motor abilities that could likely improve after interactive gaming practice.

To date there are few intervention studies that have investigated the use of interactive games in rehabilitation of children with movement disorders. Most of these are limited in size and do not provide strong evidence. In addition, these studies have primarily used complex systems which are designed for specific therapeutic purposes and require the child to come to the clinic or lab for practice [1, 2]. Two controlled studies [3, 4] and a handful of uncontrolled reports [5-13] have shown positive results on movement control. A few small studies have also demonstrated that motion interactive games can be useful to enhance children's playfulness [14], motivation for practice [15], and may have a positive impact on children's perceived self-competence and self-efficacy [16, 17]. However, research evaluating the rehabilitation value of low-cost applications that are affordable for large-scale use and especially for home-based exercise is so far limited to a few examples [3, 8]. In order to save time for participating families and costs associated with larger studies, feasibility studies examining the value of commercially available motion interactive environments are important before designing new therapeutic environments for children and planning larger controlled studies [1].

The EyeToy for Sony's PlayStation2® [1] is a low-cost motion interactive system based on a video-capture technique that allows the child to watch herself on the screen and interact with the games without having to wear any technical equipment such as a helmet, goggles or wires. The games typically involve whole body movements with elements of hitting or avoiding virtual objects displayed on the screen but can also require the user to jump, balance or run on the spot. The games in general challenge the user's overall gross motor physical abilities such as arm and leg coordination, eye-hand coordination, range of movement, and balance.

Several studies conclude that children with CP are less physically active compared to children without disabilities [18, 19]. This is a major concern since the consequences of inactivity in reducing overall health are well known. Accordingly, there is an urge to stimulate children with CP, who are already extra challenged, to become more physically active in their everyday lives [20]. To play motion interactive games can be both physically and circulatory demanding and has been shown to require more energy than playing traditionally sedentary games [21-24]. To what extent motion interactive games can increase daily physical activity among children with disabilities is to our knowledge still unknown.

The aim of this study was to explore the feasibility of using low-cost commercial motion interactive games (EyeToy) as a four week home-based intervention for children with CP. The research questions in focus were: 1) Are children motivated by practice with home-based motion interactive games, measured as intensity of practice and taking the initiative in playing? 2) Does access to motion interactive games impact physical activity of the children

[1] Sony Computer Entertainment Inc., 2-6-21, Minami-Aoyama, Minato-ku, Tokyo, 107-0062 Japan.

and is it feasible to use activity monitors to evaluate possible effects? 3) Are commercial motion interactive games challenging enough to improve motor performance in children with CP and are the instruments used in this study to assess motor ability feasible and sensitive enough to apply in future studies?

Methods

Participants

Fifteen children diagnosed with CP and with limited voluntary motor control of one or both arms were recruited from Habilitation Centres in the mid-northern part of Sweden.
The inclusion criteria were: 1) age 6-16 years, 2) attending regular school, 3) level 1-3 in the Gross Motor Function Classification System Expanded & Revised (GMFCS-E&R) [25], 4) able to understand and follow simple instructions. Exclusion criteria were: 1) profound bilateral hearing loss with the use of hearing aids, 2) severe visual impairment, 2) serious seizure disorder or uncontrolled seizures, 3) genetic and syndromic conditions, 4) diagnosis of pervasive developmental disability or autism, 5) serious or recurring medical complications, 6) botulinum toxin injection in the arm or hand within six month.

A request for participation was sent to all families identified in the area having a child who met the inclusion criteria and 42% agreed to participate in the study. One child was excluded from the study due to a botulinum toxin injection in the hand just prior to inclusion. The study population finally included 14 children, six girls and eight boys with a mean age of 10 years and 11 months (range 6-16). Characteristics of the participants are presented in Table I. The study was approved by the Regional Ethical Review Board (dnr 07-128) and written informed consent was obtained from parents and children.

Table I about here

Procedure

The design of the whole intervention is presented in Figure 1. In addition to the outcome measures reported in the present study, interviews with the parents to explore the families' experience of the intervention, and kinematic measurements of goal directed arm movements were carried out and will be presented in parallel papers.

Figure 1 about here

Each child was provided with a Sony PlayStation2® and the EyeToy game Play3, which includes about 20 different games, for use at home over a four week period. Children were recommended to practice with the EyeToy game for at least 20 minutes/day. Before and after the four weeks of home training, the child and a parent visited the university for pre- and post-assessments described below.

Measurements

Every day during the four weeks of gaming each child, assisted by parents, filled in a gaming diary. The diary was composed of short questions with pre-determined answer alternatives. Time spent on playing every day was recorded by marking one of the time sequences: 20-30 minutes; 30-60 minutes; 60-90 minutes; 90-120 minutes; more than 120 minutes. The gaming diary also monitored who took the initiative to playing each day; if the child played alone or together with parents, siblings or friends; games played; or if the child did not play that particular day. It took less than one minute every day to fill in the diary.

The physical activity monitor SenseWear Pro3 Armband[2] was used for registration of the children's activity levels by measuring Total Energy Expenditure (TEE), number of steps, and time spent as 'physically active'. 'Physically active' was defined as time spent on activity levels above three metabolic equivalent units (MET). MET values are expressed as the ratio of a person's working metabolic rate relative to the resting metabolic rate. One MET is thus the caloric consumption of a person while at complete rest [26, 27]. SenseWear Pro3 Armband is a multiple sensor device that is worn on the upper arm and collects data on skin temperature, heat-flux, and galvanic skin response. In addition the monitor includes a biaxial accelerometer and can also register number of steps. Information from the monitor is combined with the software, InnerView Professional 5.1, which calculates energy expenditure based on signals from the sensors. The ability of the SenseWear monitor combined with InnerView Professional 5.1 to measure energy expenditure during free-living conditions has been validated against doubly labelled water in overweight and obese children with accurate results [28]. To our knowledge no activity monitor has been validated so far during free-living conditions in children with CP. The children wore the monitor for a total of three periods of three days each. The first period was prior to the intervention start (baseline), the second during the first gaming week, and the third period during the last week (Figure 1).

The Movement Assessment Battery for Children-2 (mABC-2) was chosen to assess the children's motor performance because it mainly involves motor control aspects close to those children may practice while playing the EyeToy-games, e.g. goal-directed arm movements, balancing, and jumping. The test is a new version of mABC and was developed to be more appropriate for research. mABC-2 is constructed for children aged 3-16 years with coordination disorders and scores movement quality based on eight items distributed over

[2] BodyMedia Inc., 4 Smithfield Street 11th Floor, Pittsburgh, PA 15222 USA.

three subtests involving manual dexterity, aiming and catching, as well as balance. The original mABC test, has demonstrated a very high inter-rater reliability [29], and test-retest reliability and good validity [30].

In addition, the subtest 5:6 (touching a swinging ball) from Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) [31] was used to assess upper limb coordination. This test has previously been used in several studies involving children with movement disorders and interactive games [4, 10, 13]. General motor function was also assessed with the 1 Minute Walk Test which is validated in children with CP [32].

Statistical analysis

The mABC-2 and the BOTMP 5:6 tests were captured on video for later scoring. If a child was not able to perform an item successfully in the mABC-2 test, the score was set to the lowest possible score in order to obtain a total test score. All statistical calculations were performed in SPSS version 16.0[3], and data from pre- and post-assessments were compared using non-parametric statistics (Wilcoxon signed ranks test). The level of significance for all statistical analyses was set at $p<0.05$.

Results

All participating children were able to practice with the motion interactive game and were generally also capable of handling the technology and setting up the game. Only one of the 14 children (GMFCS-E&R level 3) had difficulties in coping with the game independently and needed help, especially with fast rhythmic movements and balance while playing in a standing position.

[3] SPSS Inc., IBM Company Headquarters, 233 S. Wacker Drive, 11th floor Chicago, Ill 60606, USA

Intensity and motivation for practice as reported in gaming diaries

According to the gaming diaries, the children played on average 5.5 (range 4-7) sessions every week and the mean time was 33 (range 22-52) minutes/day. The gaming intensity decreased over time from six sessions of 48 minutes each during the first week to five sessions of 26 minutes each in the last week of the intervention (difference in minutes/session p=0.001). Over the four weeks children played on their own initiative in 59% of all gaming sessions while the parents took the initiative 32% of the time. The remaining 9 % of sessions played were initiated by siblings, friends, relatives or this information was not reported. The proportion of parents' initiative for playing increased over time and approached the level of the children's during the last week. Playing together with others and especially games involving competition were most popular. The average time for sessions played together with someone was 37 minutes compared to 21 minutes when playing alone (p=0.001).

Impact on physical activity

It was feasible to use activity monitors to assess the children's daily physical activity, Wearing the activity monitor per se caused no major problems. However, four children were excluded from the analysis because they did not reach an on time of 85% each day during the measurement periods. Three of these children had occasionally forgotten to put it on and one child became ill during the last week of gaming.

Among the ten children included in the analysis eight increased their physical activity during the gaming weeks resulting in a significant increase in TEE as well as number of steps from baseline compared to both the first and last gaming week (Table II). During both gaming weeks there was also a substantial increase in time spent as "physically active" (>3 MET) with about one and a half hour/day, and surprisingly, also a significant change in time spent at the "vigorous" level (6-9 METS) with a median increase in 31 minutes/day .There were no statistical differences in the time that children wore the sensor between the three test occasions.

Table II about here

Motor performance

The sensitivity of the mABC-2 test turned out to be low for the children in this study since there were clear floor and ceiling effects. Children with GMFSC-E&R levels of two or higher had difficulties in performing several items on the tests, For example the item “Turning pegs with the affected hand” was too difficult for eight of the children, which produced tests scores in manual dexterity reflecting mainly the performance of the best hand. Ceiling effects mainly occurred in the “Balance” subtests where four children reached top scores on two or more items. Only one child completed the mABC-2 test without any top or bottom scores in any test item.

Median values and statistics on the group level for all motor performance tests are reported in Table III. For the total mABC-2 test scores there was a significant improvement at the group level. If the test scores were divided into subtests however, only improvements in the subtest “Manual dexterity” reached significance. Neither the 1 Minute Walk Test nor the BOTMP 5:6 showed significant improvements.

Table III about here

Discussion

The present feasibility study suggests that it is feasible to use low-cost motion interactive games as a home-based intervention for children with cerebral palsy in terms of motivation for practice, to promote physical activity, and enhance motor performance. The intensity in training was fairly high in this study compared to other exercise programs for children with CP [33]. However, the children's interest in gaming faded somewhat over time suggesting that these types of games are especially suitable for short periods of intensive practice, e.g. after botulinum toxin injection. A fading interest also indicates that there is a need for flexible games that adapt to the changing ability of the user and offer a continuous challenge to maintain the interest.

The children in this study substantially increased their time spent as “physically active” (>3METS) and also in “vigorous activity” (6-9METS). This increase of 31 minutes/day in “vigorous activity” indicates that the degree to which the activity levels increased could probably not solely be explained by playing motion interactive games. Although the children in our study on average practiced for 33 minutes/day they were most likely not highly physically active during the whole time. In fact former studies have concluded that the active energy expenditure while playing these games can be compared to mild to moderate physical activity (such as walking, skipping, and jogging) and there is also a considerable difference depending on the specific games, with whole body involvement generating the highest expenditure [21]. On the other hand, it is likely that access to the games contributed to the increased level of physical activity even besides time spent on gaming. For example, some parents reported that their child invited friends over to play and afterwards they did other physical activities together.

To be able to correctly assess physical activity in children with CP there is a need for reliable, affordable, and easy to use instruments. To our knowledge activity monitors have not been validated to measure energy expenditure under free-living conditions in children with CP.

However the SenseWear combined with the software Innerview professional 5:1 demonstrated good validity in overweight and obese children [28]. Considering that the golden standard, doubly labelled water, is an invasive and expensive method, activity monitors are a reasonable alternative. Nevertheless, there is a need to establish the reliability and validity of the SenseWear in this particular population.

As already mentioned, some children occasionally forgot to put on the sensor which resulted in data loss. In an attempt to prevent this we used e-mails and Short Message Service (SMS) as reminders, but perhaps these reminders were not frequent enough. A sensor that produces a warning beep when it loses skin contact or opportunities to follow and monitor ongoing measurements over the Internet might have been possible solutions. The measurement period in this study was three days times three weeks. However, the recommendation is to capture at least four days/week so in future studies a lengthened period should be applied. In addition, we believe that it is also important to capture the same weekdays in repeated measures, especially in children, as they often have regular weekly physical activities (as for example school gymnastics) that will influence the degree of activity.

The effects on motor performance after interactive practice in this study provided only vague results. There were clear floor and ceiling effects in the test results which indicate that the mABC-2 is actually not suitable for children with CP. Nevertheless, it is important to employ outcome measures that reflect the specific abilities targeted by an intervention. There are validated measurements known to detect whole body functional change over time in children with CP e.g. the Pediatric Evaluation of Disability Inventory (PEDI) and the Gross Motor Function Measure (GMFM) but these tests are not tuned to measure more specific motor control aspects and they are not validated for older children. Other validated measurements like the Melbourne Assessment of Unilateral Upper Limb Function or the Assisting Hand Assessment are more specific but also mainly focused on movement control of the hand and thus do not reflect the movements practiced in the games. For future studies it is crucial to find motor tests that are sensitive enough to capture small changes in whole body movement control.

For this feasibility study we chose four weeks of practice. However, six weeks is generally considered to be the minimum time needed to elicit a measurable effect. In future studies a lengthened period should be applied but it is also important to consider the actual number of sessions and not only intervention weeks.

In conclusion, the present feasibility study demonstrates good potential for using low-cost motion interactive games in home-based rehabilitation for children with CP. The children showed high motivation to practice with the interactive games, as measured by the time played and that children themselves took the initiative to practice. Eight of ten children increased their physical activity during the intervention period and activity monitors were feasible to use among children with CP. However, in the present study there were some problems with loss of data, which is an issue that requires thoughtful consideration in future studies. Although the results of the mABC-2 indicated that the children's motor performance improved slightly during the intervention the test suffered from both floor and ceiling effects and was not sensitive enough within the present population. There is a need for more finely tuned assessments in future studies of the effects on motor control following motion interactive gaming practice.

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Figures and Tables

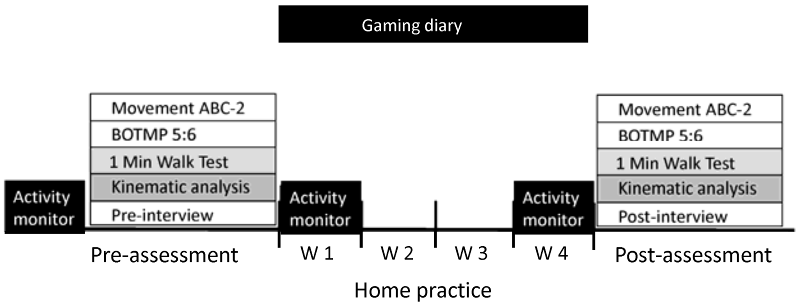

Figure 1. Schematic picture of the intervention set-up. BOTMP=Bruininks-Oseretsky Test of Motor Profiency subtest 5:6 (touching a swinging ball). W1-4=gaming week 1-4.

Table I. Characteristics of participants.

Child	Age (yy:mm)	Diagnosis	GMFCS-E&R	MACS
1	06:10	Spastic CP unilateral	1	1
2	08:07	Spastic CP unilateral	1	2
3	08:07	Spastic CP unilateral	1	1
4	08:11	Spastic CP bilateral	2	2
5	09:01	Spastic CP unilateral	1	2
6	09:04	Spastic CP bilateral	3	4
7	09:10	Spastic CP bilateral	3	1
8	10:05	Spastic CP unilateral	1	1
9	11:10	Spastic CP bilateral	1	1
10	12:01	Spastic CP unilateral	1	2
11	12:08	Spastic CP bilateral	1	2
12	13:02	Dyskinetic CP	1	1
13	15:10	Spastic CP unilateral	2	3
14	16:01	Ataxic CP	1	1

GMFCS-E&R=Gross Motor Function Classification System Expanded & Revised. MACS=Manual Ability Classification System.

Table II. Changes in activity from baseline to gaming week 1 and 4 for ten of the children, measured with the activity monitor SenseWear Pro3 Armband.

Variable	Median (IQR) baseline	Median (IQR) week 1	Median (IQR) week 4
TEE/day (cal)	1789 (900)	1950 (891)*	1966 (984)*
Steps	9815(5569)	13 755 (5188)*	12 634 (7387)*
Time over 3 MET (h:mm)	5:44 (3:25)	7:13 (3:09)*	7:16 (3:47)*

*Wilcoxon signed ranks test $p<0.05$. IQR=interquartile range. TEE=energy expenditure.

Table III. Test scores on motor performance tests.

Test	Pre-assessment Median (IQR)	Post-assessment Median (IQR)	p-value*
mABC-2 total test score	41.5 (31.25)	44.5 (28.5)	p=0.039
Manual dexterity	10.5 (16.75)	17.0 (15.5)	p=0.045
Aiming & catching	12.0 (9.25)	15.0 (8.0)	p=0.059
Balance	13.0 (18.5)	14.5 (17.25)	p=0.798
BOTMP 5:6	2.0 (3.0)	3.0 (2.0)	p=0.072
1 Minute Walk Test	90.0 (30.5)	94.0 (31,0)	p=0.078

*Wilcoxon signed ranks test. In BOTMP scores represent number of successful hits in five attempts. In the 1 Minute Walk Test scores represent meters walked. IQR=interquartile range. BOTMP 5:6=Bruininks-Oseretsky Test of Motor Profiency subtest 5:6 (touching a swinging ball).