Dynamic control of balance in children with Developmental Coordination Disorder

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Chapter 2

The impact of Wii Fit intervention on dynamic balance control in children with probable Developmental Coordination Disorder and balance problems

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ABSTRACT

Aim: The aim of this study was to examine the performance of children with and without DCD and/or balance problems on a Wii Fit dynamic balance control task. Secondly, we tested whether a period of training on a Wii Fit had an effect on balance skills, as determined by different motor tests pre- and post-intervention. Additionally, we explored whether the children experienced the intervention positively. We compared the effect of intervention with changes observed during non-intervention in a BP subgroup and in a group of typically developing children (TD group).

Method: Twenty-eight children with (suspected of) Developmental Coordination Disorder (DCD) and/or balance problems participated in the intervention study. A TD group of 15 children with typical motor development was matched with 15 children of the experimental group (BP) for gender and age for group comparison. Motor performance was assessed with the Movement Assessment Battery for Children- second edition (MABC2) and with three subtests of the Bruininks Oseretsky Test 2 (BOT2): Bilateral Coordination, Balance and Running Speed & Agility. The Wii Fit test consisted of 10 runs of the ski slalom descent game with number of gates missed and duration of descent as performance measures. The children with BP received 6 weeks of intervention playing different Wii Fit Balancing Games three times a week for 30 minutes. The TD children and half of the children in the BP group were also tested before and after a 6 weeks nonintervention period.

Results: Our results show that children with DCD and/or balance problems are less proficient than TD children in playing exergames in which dynamic balance control is needed. Training with the Wii Fit improved their Wii Fit balance skills and also had a positive impact on balance tasks of the MABC2 and BOT2. The improvements were not the result of spontaneous development and test-retest effect, since the improvement was significantly larger on MABC2 balance score and BOT2 scale score of running speed & agility and almost significant larger on BOT2 scale scores of balance and bilateral coordination, after training than after a similar period of no intervention. This was not the case for the Wii scores. Importantly, nearly all children enjoyed this Wii Fit intervention throughout the training period. Our study shows that intervention with Wii Fit games is effective and is a potential method to support treatment of (dynamic) balance control problems in children.

INTRODUCTION

Most children enjoy physical activities, such as running, walking or jumping. Physical activity is not only important for the development of motor skills, coordination, but also for fitness and overall health (Cermak & Larkin, 2002). Children with Developmental Coordination Disorder (DCD), a disorder affecting approximately 2–7% of all children, find many of these activities difficult (American Psychiatric Association, 2013; Geuze, 2010, chap. 21; Rivilis et al., 2011). Therefore they tend to withdraw from participating and may not develop adequate levels of motor skills and physical fitness. The disorder is usually not noticed until primary school, and diagnosed between six and twelve years of age (Geuze, Jongmans, Schoemaker, & Smits-Engelsman, 2001). In addition to general health issues due to sedentary life style, affected children are vulnerable to poor social competence (Bar-Or, 2005; Kalverboer, de Vries, & van Dellen, 1990), poor motivation, low self-esteem (Shaw, Levine, & Belfer, 1982; Strauss, 2000), and feelings of unhappiness (Schoemaker, Hijlkema, & Kalverboer, 1994). It is therefore important to find ways to engage these children more in physical activities in a way they enjoy, both during intervention and in daily life.

One main characteristic of children with DCD is poor postural control (Geuze, 2003). These children are less capable of controlling their balance during variable circumstances due to the fact that they respond more slowly to balance disturbances compared with their peers (Geuze, 2005; Johnston, Burns, Brauer, & Richardson, 2002). For postural control two mechanisms can be distinguished; feedback control to correct perturbed balance and feedforward (anticipatory) control. The start of well- coordinated movement is characterized by postural adaptations that anticipate loss of balance by the effects of the action itself. This process of feedforward control input prior to movement, attributed to the cerebellum, seems to be diminished in most children with DCD (Wilson, Ruddock, Smits-Engels- man, Polatajko, & Blanks, 2012), resulting in the more frequent use of feedback based strategies with longer response times, poorer timing and larger within-child variability over learning trials (Geuze & Wilson, 2008, chap. 11; Hadders-Algra, 2002).

In most of the current therapeutic approaches for children with DCD balance training is included in the treatment and has shown to be effective (Smits-Engelsman et al., 2012; Wilson, 2005). One of the important motor learning principles is practicing the task in variable, gradually more challenging circumstances (Niemeijer, Smits-Engelsman, & Schoemaker, 2007). With the development of interactive computer games, which require whole body movement and weight transfer to control the game, the so called exergames, a potential tool emerged for training dynamic balance with variability of practice. To play such games successfully a child needs adequate dynamic balance skills, which enable the child to control his or her center of gravity within the base of support while moving.

Interactive computer games, such as Wii Fit or Kinect seem to offer a new and joyful tool to encourage children to participate in physical activity that can be extended for intervention purposes. Exergames connect to the everyday world of the youngsters, and satisfy the internal drive for motivation while playing the games (Sandlund, Waterworth, & Häger, 2011).

The games are dynamic tasks that require timing within and between limbs and programming weight shifts. Children can interact naturally with the game by motion that controls the virtual character on the screen, for example by shifting weight without losing balance to cause that character to pass through gates or avoid obstacles. The exergames thus provide instant visual feedback to the child about the unconscious regulation of her or his center of gravity. The Wii Fit games promote the development of sufficient postural adjustments required for controlling dynamic balance. The task is scaled to the child's level of competence by a baseline measure. While playing, the children learn to adjust their balance in anticipation of or in reaction to visual information on the screen and may reach a higher level in the game.

In the present study we investigate whether Wii Fit Plus balance board computer games (Nintendo®) are an effective means to improve dynamic balance in children with poor coordination and balance problems (BP-group). Playing the game challenges the child to gain and improve dynamic control largely through implicit learning. Implicit learning is defined as an unintentional, unconscious form of learning characterized by behavioral improvement (Gentile, 1987; Halsband & Lange, 2006). It has been suggested that children with DCD often fail to learn motor tasks implicitly (Schoemaker, 2008, chap. 14) and that children with DCD need ample practice to master a skill and adapt to new motor strategies. Positive reinforcement of performance by visual information encourages the child to persist in its efforts and lifts emotional barriers by the experience of success in the motor domain. Halsband and Lange (2006) states that feedback processing by use of proprioceptive and visual information as well as error detection and correction are the critical aspects of motor control coded by cerebellar structures. A study using a force plate platform to train children afflicted with cerebral palsy (CP) resulted in a significant improvement in the ability to recover stability after a perturbation in forward and backward horizontal translation, as demonstrated by reduced center of pressure area and time to stabilization (Shumway-Cook, Hutchinson, Kartin, Price, & Woollacott, 2003). Studies in children with DCD using exergames to improve balance skills are scarce. However, in several clinical populations of patients with acquired brain injury or children with CP, intervention with exergames was shown to improve static balance (Gil-Gómez, Lloréns, Alcañiz, & Colomer, 2011), postural control, visual-perceptual processing and functional mobility (Deutsch, Borbely, Filler, Huhn, & Guarrera-Bowlby, 2008) and balance skills (Jelsma, Pronk, Ferguson, & Jelsma-Smit, 2012).

The first aim of this study is to examine differences in dynamic balance control on a Wii Fit game between children with balance problems (BP-group) compared to children with adequate balance skills (TD-group). The second aim is to evaluate the change after aWii Fit intervention for the children with BP by comparing pre- and post-intervention Wii Fit scores, balance and motor skills as measured by different motor tests. The third aim is to examine whether this change over the intervention period is larger than change over a similar non-intervention period. Finally, we evaluate whether children enjoy the intervention during the whole period since usually children grow aversive to interventions that they find difficult to perform.

METHODS

Subjects

Criteria for inclusion in the intervention group were children aged between 6 and 12 years old, a total test score ≤16th percentile on the Movement Assessment Battery for Children-2 (MABC2) and ≤16th percentile score on the component score for balance (static and dynamic balance). We refer to this group as children with balance problems (BP-group). Inclusion criteria for the typically developing group (TD group) were a total test score >16th percentile on the MABC2 and a component balance score >16th percentile. Excluded from both groups were children with a medical, neurological and mental disorder or IQ < 70.

Children suspected of poor coordination and balance problems were preselected from two primary schools for special education (n = 20) and through a practice for paediatric physical therapy (n = 11) in the Netherlands. The pre-selected children were all tested with the MABC2. Three children were excluded because they scored >16th percentile on the total and the balance scores of the MABC2, resulting in a BP group of 28 children (see Fig. 2.1). Any learning disorder when present has been noted for reasons of description of the subject group. From the school records it was found that seven children had a primary diagnosis of DCD as assessed by a physician, eight children had a primary diagnosis of PDD-NOS and one child of ADHD as assessed by a psychiatrist, 12 children had no formal diagnosis. The mean IQ of the children in the BP group was 79.4 (SD = 10.3, range 67–100). One child scored a total IQ of 67, but because of its score of 79 on the Verbal IQ scale the child was included in the clinical group.

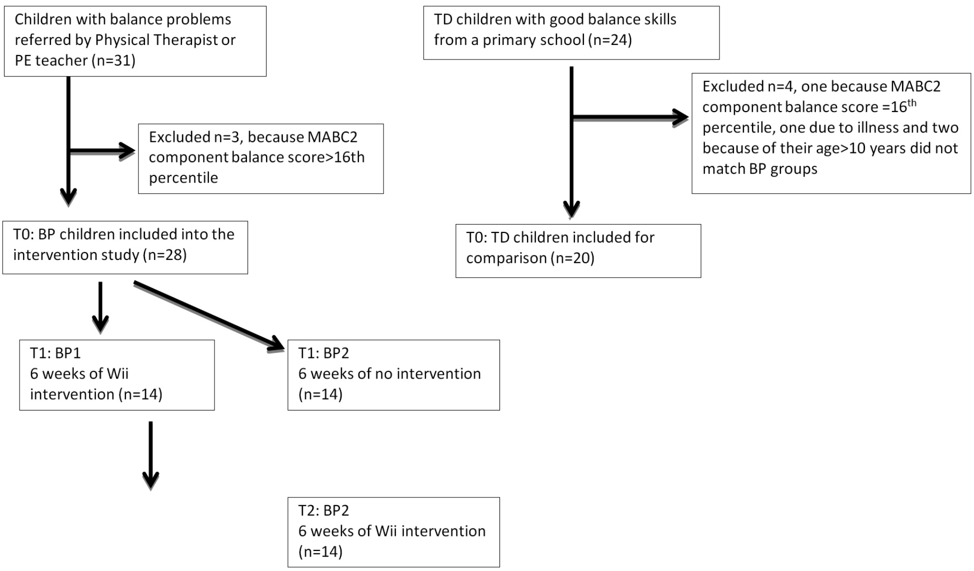


Fig. 2.1. *Flow diagram selection of subjects*

A typically developing group (TD group) of 22 children with normal motor development was recruited at a regular primary school (see Fig. 2.1). One child was excluded because of a percentile score of 16 on the MABC2 and one due to illness. Demographic characteristics are presented in Table 2.1.

This project has been approved by the Ethics Committee of the Department of Psychology of the University of Groningen. Written informed consent was obtained from all parents and assent from each child.

INSTRUMENTS AND APPARATUS

The movement ABC2

The Movement Assessment Battery for Children-second edition (MABC2) was used to test the children's motor performance. The MABC2 is a standardised and norm referenced test that is validated for the Dutch population of children aged 3–16 years and is divided into three age bands ranging from 3 to 6, 7 to 10 and 11 to 16 years (Henderson, Sugden, & Barnett, 2007; Smits-Engelsman 2010). The test has three sections: Manual Dexterity (three items), Aiming and Catching (two items) and Balance (three items). The balance section has one item of static balance (standing on one leg) and two items of dynamic balance (walking over a line and hopping or jumping). Each raw score is recoded into an item standard score; per section a component standard score can be derived. The sum of all eight item standard scores can be recoded into a total standard score (range 1–19; mean score = 10; SD = 3) and percentile score. A standard score >7 is regarded average/normal motor performance, 6–7 is considered to be indicative of at risk for motor problems whereas a score at or below the 5th standard score is indicative of a serious motor problem.

The concurrent validity of the MABC2 with the Bruininks-Oseretsky test of Motor Proficiency (BOTM; $r = 0.58$, $p < 0.001$) (Jelsma, van Bergen-Verhoef, Niemeijer, & Smits-Engelsman, 2010) and with the Körper Koördinationstest für Kinder (KTK; $r = 0.62$, $p < 0.001$) (van Beek, Booij, Niemeijer, & Smits-Engelsman, 2010) is good. For the test–retest reliability of age band1 ICC's were found of 0.95–0.98 and the inter-rater reliability was 0.96 (Henderson et al., 2007; Smits-Engelsman, 2010). Based on the standard error of measurement (SEM) in the normative sample a smallest detectable difference (SDD) of 3 in the standard score of the MABC2 is required for individual interpretation of progress (Smits-Engelsman, 2010).

Bruininks Oseretsky test of motor proficiency 2 (BOT2) (Bruininks & Bruininks, 2005)

All children were tested with three subcomponents of the Bruininks Oseretsky test second edition. These three components of the test were chosen as an evaluation tool to test a broader range of balance tasks because of the limited number of balance items of the MABC2. The component bilateral coordination consists of seven tasks of bilateral assignments in standing (4) or sitting position (3). The component balance consists of seven static balance tasks and two dynamic balance

Table 2.1 Demographic and clinical characteristics of the groups of typically developing children (TD) and children with balance problems total group and per subgroup (BP1 and BP2 group).

Groups	TD (n = 20)	BP total (n = 28)	BP1 (n = 14)	BP2 (n = 14)
Mean age in months (SD)	102.5 (12.2)	98.4 (16.6)	104.8 (17)	92 (14.1)
Range	77–129	71–136	75–136	71–114
Mean height in cm (SD)	136.2 (9.1)	134.3 (9.4)	137.9 (9.2)	130.8 (8.6)
Range	114–149	119–156	124–156	119–146
Mean weight in kg (SD)	32.2 (7.9)	33.1 (11)	38.6 (12.3)	27.9 (6.5)
Range	20.8–46.1	21.4–70.2	26.9–70.2	21.4–42.5
Sex ratio f/m	.45	.36	.36	.36
Mean MABC2 (SD)	13.4 (2.7)	2.5 (1.3)	2.2 (1.1)	2.7 (1.5)
Range	9–19	1–6	1–4	1–6
Mean MABC2 balance (SD)	11.3 (2.2)	3.3 (1.6)	3.4 (1.5)	3.1 (1.4)
Range	9–17	1–7	1–7	1–5
Wii Fit experience	45%	30%	43%	14%
Outdoor ski experience	55%	4%	7%	0%
BOT2 bilateral coordination	19.4 (1.8)	10.1 (3.3)	9.2 (2.2)	10.9 (4.0)
Range	14–21	4–16	6–14	4–16
BOT2 balance scale	20.3 (2.9)	7.6 (2.8)	7.4 (3.0)	7.9 (2.7)
Range	16–24	4–17	4–17	4–13
BOT2 running speed & agility	16.4 (2.9)	8.9 (3.1)	8.3 (3.1)	9.6 (3.2)
Range	11–22	4–15	4–14	5–15

tasks. The component running speed & agility consists of five dynamic balance tasks.

Each raw score is converted into a point score. All point scores are cumulated into a total point score for each subtest. Per subtest, total point scores are converted according to sex- and age specific norm tables into subtest scale scores. These scale scores indicate performance well below average (1–5), below average (6–10), average (11–20), above average (21–25) and well above average (26–30). Inter-rater reliability for scale scores are consistently high for subtest balance (0.99), bilateral coordination (0.98) and running speed & agility (0.99) (Bruininks & Bruininks, 2005). The standardization of the BOT2 is based upon an American norm sample. Based on the SEM of the BOT2 subtest scale scores of the normative sample a SDD of 2 is considered the minimal required change for individual progress (Bruininks & Bruininks, 2005).

Wii Fit ski slalom test

The Wii is an interactive video computer system (Nintendo®) with a remote controller. The Wii Fit Plus includes a Balance Board (WBB) with Bluetooth wireless connection that is battery operated. The balance board has four force plate sensors, one in each corner, used to measure the child's weight, and to calculate center of pressure (COP) and weight distribution. When the child is standing on the board it can steer the virtual character, called Mii, by moving the Centre of Mass sideways or forward and backward. The WBB software calculates the COP of these displacements, resulting directly in the movements of the Mii. In the Wii Fit ski slalom game, when the child shifts his or her center of mass forward or backward anteriorly/posteriorly) the skiing character speeds up or slows down; shifting the child's center of mass to left and right (laterally) will direct the skier sideways. The sensitivity of the WBB is normalized according to the child's weight, which is a standard procedure of Nintendo Wii. The goal of the game is to ski through 19 gates along a ski slope without missing a gate and as fast as possible. Children are instructed to make the Mii pass through the gates as it descends the slope. The number of gates the Mii passes or misses is registered as well as the time between start and finish. The spatial layout of the gates on the slope is invariant. The individual gates vary in their lateral distance from the middle of the slope and their distance along the slope. Immediately after a run the Wii score of the ski slalom game is presented on the screen. The number of missed gates and the time needed from start to finish are noted. The validity and reliability of the Wii Fit Balance Board has been found good compared to a laboratory-grade force platform (FP) used as the gold standard by Clark et al. (2010). Their findings suggest that the WBB is a valid tool for assessing standing balance.

Enjoyment scale

An enjoyment scale of 5 points with smiley faces (0 is no fun at all; 4 is super fun) has been developed for this study to evaluate how much the child enjoys playing a Wii game at a certain moment in time (see Fig. 2.2).

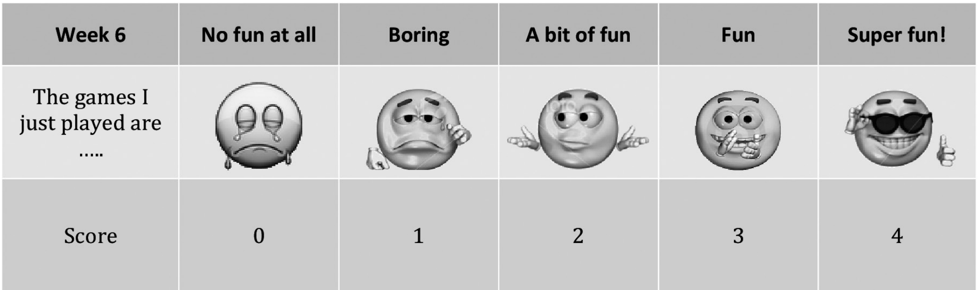
Design of the study

This prospective study is a combined interventional and nested case control study, in which comparison with case controls, intervention and time has been made. The BP group was divided into two subgroups consisting of 14 children each. One group (BP1) started the intervention of 6 weeks immediately after the selection, while the other group started with a period of no intervention (BP2). The BP2 group then continued with 6 weeks of intervention. Table 2.2 gives an overview of the design of the study. Before and after the 6 week periods children were tested with the MABC2, BOT2 and Wii Fit ski slalom test. The BP2 group thus was tested three times.

Procedure

First, all children were tested on the MABC2, BOT2 subtests bilateral coordination, balance and running speed & agility for baseline measures. All children were tested individually in their own school environment. Five testers (two Paediatric Physical therapists, including the first author and three 4th year students of the Sports Academy, who had received additional training on the administration of all outcome measure prior to commencement of the study) administered all motor pre and posttests.

The testers were not blinded but children were randomly assigned to testers. Children whose MABC2 scores permitted their inclusion in the study completed the Wii Fit test in another session 1 week later. The Wii Fit ski slalom test consists of ten repetitions of the ski slalom game. Each game is called a run. After the fourth run, according to protocol, each child was given instructions how to improve playing the game. The first author supervised the children on the Wii Fit test assisted by a research assistant.



Week 6	No fun at all	Boring	A bit of fun	Fun	Super fun!
The games I just played are …..					
Score	0	1	2	3	4

Fig. 2.2. *Enjoyment scale*

Table 2.2 Design of the study with T0, T1 and T2 indicating the moments when children were tested on their motor proficiency and Wii Fit ski slalom skills, and period 1 and 2 indicating 6 week periods without or with intervention.

Group	Time T0	6-week period 1	Time T1	6-week period 2	Time T2
TD (n=20)	MABC2, BOT2, Wii Fit test	No intervention	MABC2, BOT2, Wii Fit test		
BP1 (n=14)			MABC2, BOT2, Wii Fit test	Wii intervention Enjoyment scale	MABC2, BOT2, Wii Fit test
BP2 (n=14)	MABC2, BOT2, Wii Fit test	No intervention	MABC2, BOT2, Wii Fit test	Wii intervention Enjoyment scale	MABC2, BOT2, Wii Fit test

TD= Typically Developing group,
BP= group of children with balance problems

The intervention consisted of practicing the Wii Fit Plus Balancing Games 30 min at a time, three times a week for 6 weeks. Intervention was given by 4th year students of the Sports Academy, or Medical Pedagogy, under supervision of the first author. Three children participated simultaneously in the training on the three Wii Fit Plus systems available in a single room. They were not allowed to play ski slalom, since the ski slalom game was used to test Wii Fit skills. Children could choose from 18 Wii balancing games and played each game twice, before being allowed to continue to one of the other games (http://www.nintendo.co.uk). This procedure ensured sufficient variety of training and equal time spent in training. The trainer recorded the chosen games in each child's log, and motivated the children while playing. At the end of the first, third and sixth week of intervention the children were asked to choose a face on the Enjoyment Scale that matched their feeling of enjoyment during this session.

Data analysis

Demographical data were compared between groups using independent *t*-tests. Means over 10 runs were calculated for Wii time (s) and the number of missed gates. To combine speed and accuracy in one measure, we calculated a Wii *z*-score as follows. *z*-scores were based on the SD of the distribution of scores in the TD group at T0 (mean $z = 0$). Thus any difference in Wii Fit z-scores between groups or time is relative to the TD group at T0. The individual data of Wii seconds and Wii missed gates then were standardized into *z*-scores and summed into a single Wii z-score, a lower score implying a better Wii performance.

Given the slight differences in age and weight between the BP1 and BP2 groups, differences in MABC-2 total score at baseline were tested using ANOVA, showing no difference ($F(1, 27) = 1.6$, $p = .22$). Multivariate no differences were found either on MABC2 balance, BOT2 subtests bilateral coordination, balance, running speed & agility and Wii z-score ($F(5, 22) = 1.1$, $p = .41$). Univariate analysis supports the lack of differences (all $p > .17$). Data of the BP1 and the BP2 groups were therefore combined for the comparison with the TD group and for evaluation of the intervention effect.

Since previous experience with skiing might have an effect on performance this was checked. In the BP group only one child had ski experience but performed less proficient on the Wii compared to the BP group average. In the TD group no significant difference was found on any of the motor test scores between children with and without ski experience (all $p > .266$). Therefore the analyses are not corrected for ski experience.

For the first research question a MANCOVA was used to test for difference between TD group and BP group at baseline for Wii z-score, BOT2 bilateral coordination, balance and running speed & agility. Since previous Wii Fit experience might have an impact on the outcome of the group comparison, Wii Fit experience was used as a covariate. The multivariate tests indicate significance of common effects to which all variables in the analysis contribute. For the second research question a General Linear Model (GLM) multivariate repeated measures analysis examined changes over the intervention period (BP group between T1 and T2). First, the total test scores of MABC2 and Wii *z*-score were entered, and in a second analysis all subtests: MABC2 component balance, BOT2 scale score bilateral coordination, balance, running speed & agility, Wii missed gates and Wii seconds. Lastly, to test for task specific effect of training, the MABC2 components manual dexterity and aiming & catching were analyzed. All three analyses were again adjusted for Wii experience by using it as a covariate. Partial eta squared $\eta_p^2$was calculated to determine the effect size (interpretation: .01–.05 a small effect; .06–.14 a medium effect; and .14 or greater a large effect (Field, 2010)).

To analyze whether change over the intervention period is larger than change over a similar nonintervention period (third question), GLM multivariate repeated measures analysis was applied using the data of the BP2 group, adjusting for Wii experience. Firstly, dependent variables of total scores MABC2 and Wii z-score; secondly the subtests (MABC2 component balance, BOT2 scale score bilateral coordination, balance, running speed & agility, Wii missed gates, Wii seconds). A significance level of .01 has been adopted to compensate for multiple testing when four or more dependent variables are included in multivariate testing; if two dependent variables are included in the multivariate analysis a was set to .025.

For child nr. 40 (BP2 group) no T2 data of the BOT2 Bilateral Coordination were available since he refused the retest. We decided to impute the value measured at T1 for this child implying no change due to intervention in this child, thereby preventing the effect of intervention to be overestimated.

The frequencies of the enjoyment scale are reported to evaluate how the children enjoyed the exertraining at the first, third and final week of intervention.

RESULTS

Baseline differences between the TD and BP groups

At time of first measurement the BP group scored a mean total standard score of 2.5 (SD 1.3) on the MABC2 and 3.3 (SD 1.6) on the component balance, while the TD group scored respectively 13.4 (SD 2.7) and 11.3 (SD 2.2). No significant differences were found between the BP and TD group for age, height and weight (all $p > .359$) nor gender ($p = .527$; TD girls 45% and BP girls 36%). The BP group scored a mean of 9.7 (SD 2.6) missed gates and 38.7 (SD 3.7) seconds of descent, while the TD group missed 5.0 (SD 2.1) gates and used a mean of 41.8 (SD 3.5) seconds from start to finish.

Multivariate analysis, corrected for Wii experience, showed that the TD group and the BP group differed significantly at baseline on the Wii z-scores, BOT2 scale score of bilateral coordination, balance and running speed and agility (multivariate ($F(4, 42)=67$, $p < .001$, $\eta_p^2=.86$) and for all these variables also on the univariate test (all $p < .01$). Mean scores of the BP group were all significantly poorer than those of the TD group (see Table 2.3).

Effect of intervention

The BP group received an average of 16.6 (range 11–18) sessions of intervention with a total duration of eight hours and thirty minutes. On average 1.3 sessions (SD 1.6, range 0–7) were missed due to illness or school activities, such as visits to a museum or library. Multivariate test results show significant improvement for the total MABC2 test score and Wii *z*-score ($F(2, 25) = 17.4$, $p < .001$, $\eta_p^2 =.58$, time x Wii experience $p= .263$) and for MABC2 balance score, BOT2 subtest scores and Wii scores ($F(6,21)=20.7$, $p < .001$, $\eta_p^2=.86$, time x Wii experience $p = .015$). No significant differences were found for the multivariate analysis of MABC2 components aiming and catching and manual dexterity ($F(2,25) = .85$, $p = .442$, $\eta_p^2=.06$, time x Wii experience $p = .633$). Table 2.4 lists the means and univariate outcomes of these tests. Only one significant interaction between Wii experience and intervention (time) was found for the BOT2 bilateral coordination ($p = .002$). Being initially equally proficient in bilateral coordination before treatment (means 9.9 and 9.8) the mean of test scores of children without Wii experience improved (mean 13.4) and those with, did not (mean 9.6). Analysis of the intervention effect showed a significant improvement between T1 and T2 on all variables, except for Wii time, MABC2 manual dexterity and aiming and catching. Partial eta squared showed strong effect sizes. Post-intervention the BP group missed on average 1.8 gates fewer compared to their pre-intervention Wii performance.

Table 2.3 Mean scores of TD and BP group at baseline measure with univariate statistics of TD-BP group differences.

	TD group (n =20) mean (SD)	BP group (n = 28) mean (SD)	F	p-Value	η_p^2	Group*Wii experience (p-Value)
Wii *z*-score	0	1.4	9.6	.003*	.18	.242
BOT2 bilateral coordination[a]	19.4 (1.8)	10.1 (3.3)	128.4	< .001*	.74	.402
BOT2 balance[a]	20.3 (2.9)	7.6 (2.8)	225.6	< .001*	.83	.127
BOT2 running speed and agility[a]	16.4 (2.9)	8.9 (3.1)	73.4	< .001*	.62	.192

* p-Value significant at a = .01.
[a] BOT2 in scale scores.

Over the intervention period the mean Wii *z*-score of the BP1 group changed from .98 to –.35, which means that after intervention they improved to a level better than the average of the TD group at T0. The mean Wii *z* -score of the BP2 group changed from 1.6 to .30 (see Table 2.5). Over the intervention period the total BP group improved on average by 1.26 on the Wii *z* -score.

Table 2.4 Mean scores of children with balance problems (n = 28) at pre and post- intervention (time), univariate pre-posttest outcome after controlling for the effect of Wii experience.

Test	Pre intervention mean (SD)	Post intervention mean (SD)	F	p-value	η_p^2	Time x Wii Experience (p-value)
MABC 2 total standard score (SD)	2.6 (1.6)	4.2 (3.0)	14.0	.001*	.35	.313
Wii *z*-score	1.3(2.1	-.02 (1.5)	18.7	< .001*	.42	.218
MABC2 balance standard score	3.3 (2.0)	6.1 (2.8)	27.8	< .001**	.52	.141
BOT2 bilateral coordination scale	9.8 (2.8)	12.3 (4.5)	40.0	< .001**	.61	.002
BOT2 balance scale	7.4 (2.9)	10.6 (4.5)	22.9	< .001**	.47	.094
BOT2 running speed & agility scale	8.9 (3.0)	12.8 (3.8)	30.7	< .001**	.54	.471
Wii # missed gates	8.8 (3.5)	7.0 (3.7)	10.0	.004**	.28	.767
Wii time (s)	39.9 (4.0)	38.4 (3.4)	4.0	.056	.13	.256
MABC2 manual dexterity	4.9 (2.8)	5.3 (3.0)	1.6	.219	.06	.284
MABC2 aiming & catching	5.0 (2.5)	5.4 (3.3)	0.8	.376	.03	.416

* p-Value significant at a = .025; ** p-Value significant at a = .01

Change due to intervention compared to change during non-intervention period

Table 2.6 lists the mean change of the motor and Wii scores of the BP2 group between T0 and T1 (non-intervention period) and between T1 and T2. Multivariate (BP2 group only), significant difference was found on the repeated measures in time on the total test score of the MABC2 and the Wii *z*-score ($F(2, 11) = 5.3$, $p = .025$, $\eta_p^2=.49$). Multivariate outcome of all subtests (MABC2 balance, BOT2 scale scores and Wii scores) is significantly different as well ($F(6, 7) = 12.4$, $p = .002$, $\eta_p^2=.91$). Univariate outcome shows that the change in Wii scores from T0 to T1 and from T1 to T2 is not significantly different, and that the change between T1 and T2 is significantly greater than between T0 and T1 for the MABC2 balance score and BOT2 scale scores of bilateral coordination and running speed & agility. The mean difference of these tests between T2 and T1 was beyond the smallest detectable difference and the effect sizes are large. The mean improvement over the intervention period (T1 and T2) compared to the change over the non-intervention period (T1 and T0) for the BOT2 scalescores of balance ($p=.012$) is close to the chosen level of significance and shows a large effect size ($\eta_p^2=.42$). Between T2 and T1 this mean difference was larger than the SDD of the tests.

Individual change in classification

Individual improvement of motor proficiency between pre and post- intervention was defined as a change in score larger than the SDD of MABC2 and BOT2 normative population scores. Based on this definition eight children improved on the MABC2 total score. For four of these children this implied a change in classification from the clinical range towards the 'at risk' range and for one child from 'at risk' to the normal range on the MABC2 total score. For the MABC2 component balance thirteen children improved, two of these children moved from the clinical range to the 'at risk' range, seven children moved towards the normal range and two children moved from the 'at risk' range towards the normal range. One child moved from the at risk range to the clinical range at T2.

Table 2.5 Mean Wii *z*-scores at T0, T1 and T2 for each group.

z-wii[a]	T0		T1		T2
TD group	0				
BP1 group	.98	Intervention	-.35		
BP2 group	1.72		1.58	Intervention	.30

[a]Wii *z*-score is the sum of *z*-missed gates and *z*-seconds

The BOT2 component balance showed positive results for eighteen children; five children moved from well below average to below average and nine children moved up from below towards average or even above average and four did not change classification. Two children (child nr. 14 & 60) showed negative change, of which one child changed from average towards below average. For the BOT2 component bilateral coordination sixteen children improved; eight children improved at T2 to average or even above average. One child (nr. 20) moved from average to below average.

On the component running speed & agility twenty-two children improved over the intervention period by at least the SDD; five children changed classification from well below average to below average and seven children improved to an average score; one child (nr. 23) changed negatively from average to below average.

Table 2.6 Mean difference scores between successive test moments of the BP2 group. No intervention between T0 and T1; Wii intervention between T1 and T2. Test statistics of repeated measures indicate if T2 - T1 differences are significantly greater than T1 - T0 differences, with effect sizes and after controlling for the effect of Wii-experience.

Mean difference (99% CI) n = 14	T1 - T0	T2 -T1	F	p-value	η_p^2	Time x Wii experience (p-value)
MABC2 total[a]	.36 (–.26;.98)	2.1 (–.15;4.4)	7.3	.020*	.38	.635
Wii z-score	–.13 (–1.7;1.5)	–1.3 (–2.4; –.16)	3.3	.095	.22	.227
MABC2 balance[a]	.14 (-.88;1.2)	3.9 (1.7;6.2)	14.2	.003**	.54	.926
BOT2 bilateral coordination[b]	-.50 (-2.4;1.4)	3.0 (.81;5.2)	10.6	.007**	.47	.242
BOT2 balance[b]	-.43 (-2.2;1.4)	3.9 (.39;7.5)	8.8	.012	.42	.454
BOT2 running speed and agility[b]	.07 (-1.7;1.8)	4.6 (2.2;7.1)	21.2	.001**	.64	.317
Wii missed gates	-1.8 (-3.9;.42)	-1.7 (-4.0;.58)	0	.99	0	.867
Wii time	2.4 (-1.9;6.7)	-1.7 (-5.2;1.9)	4.6	.054	.28	.196

* p-Value significant at a = .025.
** p-Value significant at a = .01.
[a] MABC2 in standard scores.
[b] BOT2 in scale scores.

Table 2.7 Frequency of enjoyment scale scores for the BP group during intervention

Amount of fun	After 1st week	After 3rd week	After 6th week
Superfun (4)	24	22	20
Fun (3)	2	3	4
A bit of fun (2)	1	2	2
Boring (1)	0	0	1
No fun at all (0)	1	1	1
Total	28	28	28

Enjoyment scale

Most of the children with balance problems enjoyed the intervention during 6 weeks (Table 2.7). Two children were notable in their choices. One child scored a zero in the first week; after 3 weeks this child scored a 4 and after 6 weeks a 4 again. The other child scored a 2 after the first week, a zero at 3 weeks and a zero again after 6 weeks. Two more children reported a slight loss of interest, but still enjoyed playing the games during the intervention.

DISCUSSION

The aims of this study were four fold. First group differences between children with and without balance problems (BP) on motor, balance and Wii Fit game scores were tested. Secondly, we examined whether a period of training on a Wii Fit had a measurable effect on balance skills, as determined by different motor tests. Thirdly, it was examined whether the effect of intervention was larger than change over a similar non-intervention period. Finally, we explored motivation to participate in intervention over time. The main outcomes of this study are as follows: as expected, children with BP had poorer performance in the Wii Fit ski slalom game compared to typically developing children.

The Wii intervention in the BP group, after correction for Wii experience, resulted in improved performance on the motor tests. When corrected for the spontaneous change seen after an equally long no-intervention period, this difference remained significant for the MABC2 balance test and the BOT2 bilateral coordination and running speed &agility scale score, and was close to significance for the BOT2 balance subtest. The Wii performance, corrected for Wii experience, improved over a non-intervention period in the BP2 group and continued improving over the intervention period. Only one child reported loss of motivation over the intervention period.

Group comparison revealed significant differences between groups on Wii *z*-scores and BOT2 subtests on the baseline measure. On average children with BP missed 4.7 more gates and their mean *z*-score of Wii performance (sum of *z*-missed gates and *z*-seconds) was 1.35 SD below the average of the TD group at baseline. Based on these differences one might conclude that poor motor performance is associated with poor performance on the Wii Fit ski slalom game.

When evaluating the effect of aWii Fit intervention for children with BP a consistent positive effect on the dynamic control and balance skills of children with probable DCD and balance problems was found. A significant change was seen in all variables tested but one (time needed to perform the Wii test). Both motor scores on the balance items of MABC2 and the BOT2 balance subscale improved after the intervention period. This result contradicts the general opinion that children with DCD often fail to learn motor tasks implicitly (Hadders-Algra & Brogren-Carlberg, 2008, chap. 1). Implicit learning, consisting of unintentional, unconscious learning, seems largely present in playing the Wii Fit balance games, since the child concentrates on how to play the game and how to improve by practice and trial and error. It may be questioned whether the intervention offered true implicit learning. The knowledge of results in terms of a Wii score and number of gates missed and the explicit instruction after the fourth run, during the Wii Fit test, may be interpreted as feedback used in explicit learning. However, the Wii Fit tasks can be considered as goal-oriented, timed, visual-motor tasks requiring repetitive body movements while remaining within the base of support dependent on augmented on-line visual and proprioceptive feedback. Internal modeling seems to be effectively stimulated while the child receives feedback, which can be regarded as largely implicit learning. This idea is supported by the view of Halsband and Lange (2006) that feedback given by use of proprioceptive and visual information as well as error detection and correction can improve motor control. Given that children with DCD have problems generating or using predictive adjustments of body position as a means of correcting actions in real time (Wilson et al., 2012), the combination of augmented feedback and repeated training in various games appears to have a positive impact on balance tasks.

When the effects of intervention were tested against change over a similar non-intervention period, consistently larger change due to intervention was found for motor test scores related to dynamic control of balance but not for fine motor control and ball skills, and, remarkably, not for the Wii scores. The improvement on the Wii Fit ski slalom test due to intervention was comparable to the spontaneous improvement over the previous non-intervention period. Apparently, the children showed similar learning effects in Wii scores over the non-intervention and the intervention periods. Improvement after the non-intervention period may be due to retest learning effects over the 10 runs and/or spontaneous development of motor coordination over the 6 weeks period, processes that may also have been effective over the 6 weeks period of intervention. However, learning curves tend to level off and have their largest change early in the learning period. Our data are compatible with the interpretation that the intervention enhanced dynamic balance control over the second period of 6 weeks. However, more detailed research of the dynamics of learning phases in Wii tasks, and use of more rigorous design is necessary to fully understand and confirm the intervention effect on the Wii dynamic balance task.

Obviously, children were not allowed to train the ski slalom game, but practiced many shifts of weight in the other games, which might have transferred to other balance tasks. The effects of intervention on the balance items of the MABC2 and BOT2 are much more clear-cut. Here the improvement due to intervention was significantly larger than the change occurring over the non-intervention period.

The importance of implicit learning is increasingly recognized in existing treatment methods, such as physical therapy, Neuromotor Task Training (NTT) or motor imagery training (Niemeijer et al., 2007; Smits-Engelsman et al., 2012; Wilson, 2005). Exergames may have an added value for existing intervention programmes that strongly rely on implicit learning. We conclude that the effect of the intervention is generalized to other motor tasks in which anticipatory adjustment of body position is involved. This is evident from the significant improvement of MABC2 component balance, BOT2 subscales bilateral coordination and running speed and agility and the trend in improvement of BOT2 balance. This was not the case for manual dexterity and aiming and catching. Generalization of the positive effect of Wii intervention thus seems limited to motor tasks that are closer to the task trained.

At the individual level the majority of children clearly improved in motor performance and for about half of them this implied a change in clinical classification. Fifteen out of 28 children shifted positively in clinical classification one category or even two on the component balance of the MABC2, after intervention. Only one child scored a lower level after training. On the level of clinical classification based on the total MABC2 score five children moved up in classification. This change of classification on the MABC2 was confirmed by the improvement in classification of twelve children on the BOT2 subscale balance. Nearly all children showed improvement after an intensive 6-weeks Wii intervention, with a large group of children improving more than the SDD of the tests. The children who still scored within the clinical range may be advised to continue training in their home environment. The Wii Fit training program provides the opportunity to extend exercising in home- or school settings. Future study of the learning curves of children with balance problems and the underlying deficits, and a follow up study may provide insight in the characteristics of effective training over a longer time span.

The underlying deficits causing poor motor performance in children with DCD are still poorly understood. Visser (2003) and Geuze et al. (2005) argued that there is indirect but converging evidence indicating that cerebellar dysfunction contributes to the motor problems of children with DCD (see also Smits-Engelsman, Van Galen, & Schoemaker, 1997). Impaired cerebellar functioning is manifested by poor balance control. The cerebellum can be considered a main integrator of on-line visual and proprioceptive feedback. Patients with cerebellar dysfunction show increased variability in motor timing (Claassen, Jones, & MinhongYu, 2013; Molinari et al., 2005). Consistent timing and anticipation are important in the exergames and fast online processing will improve the scores. The cerebellum has a major role in anticipating events and thus adapting movements fluently to their goal (Becker, Morrice, Clark, & Lee, 1991; Salman, 2002; Visser, 2003; Hardwick, Rottschy, Miall, and Eickhoff, 2013). It appears that regular practice on the variable repetitive Wii Fit tasks positively influences the ability to anticipate movements.

Finally we evaluated whether children enjoyed the intervention over the six week period of intervention, since children usually will be averse to games or interventions that they find difficult to perform and may lose interest when interventions extend over a long period of time. Our data show that the children enjoyed playing the Wii games and this continued over the intervention period, except in one case. For children who need treatment for a longer period of time, the aspect of enjoyment and therefore the ability to increase learning is of great importance. Practice, active participation and goal orientated movement are recognised as essential components of effective motor learning (Flynn, Palma, & Bender, 2006). We conclude that exergames like the Wii Fit may be considered suitable tools to extend intervention to home- or school situations and that these games encourage children to actively participate over a time period that is typical for intervention.

Strength and limitations of the study

This is the first study that provides evidence that an exergame as a means of intervention for (dynamic) balance problems improves children's balance skills such as measured by the MABC2 and BOT2. We realize that a full randomized clinical trial (RCT) design is preferred over the half group cross-over design as used in our study. However, the partial cross over design is a valuable method for gathering evidence. Due to practical limitations and researchers being involved in measurements, the data collection has not been blind as to group membership and time of measurement. An optimal design (RCT) would neutralize the above limitations. Recently, Hammond, Jones, Hill, Green, and Male (2013) performed a small pilot study using a 4 week Wii Fit intervention versus a school-run Jump Ahead intervention. They used a cross-over design with a slightly different population of children at risk for DCD. They report a positive effect of the Wii Fit training on the performance of the BOT2 test (short form) and a positive change in children's perceived performance. Together with the present results this strengthens our conclusion that the 6 week Wii Fit intervention is effective in improving motor performance in children 'at risk for DCD' and balance problems.

One other aspect that needs to be considered is the difference in mean IQ of both groups. In our BP group the mean IQ was 79 and for the TD group we assume a mean IQ of 100, since none of the children repeated a class; thus, the IQ of the BP group is 1.4 SD below the average IQ of the TD group. According to Smits-Engelsman and Hill (2012) for each SD lower IQ, a mean loss of 10 percentile on motor performance should be taken into account. Applying the formula makes clear that the BP group may be expected to show a 14 percentile lower score on the MABC than the TD group; the group difference is however 86 percentile (TD group 13.4 standard score corresponds to 87 percentile; BP group 2.5 standard score corresponds to 0.75 percentile), leaving a still significant difference in motor performance between the groups. Whether the poor motor performance can be explained by problems in motor learning will be the topic of a future study.

Previous Wii experience, included as covariate in the analysis, did not have a significant impact on differences between groups or the effect of the intervention except for BOT2 bilateral coordination. We think the latter may be a chance finding, because Wii experience did not have significant effects on any of the other variables. Further study will have to confirm this. None of the games played on the Wii Fit (for instance skiing or skateboarding) accurately represent sports or activities in real life. Still, a transfer effect seems to have taken place in the BP group towards real tasks that need a high level of balance control, like items such as stepping over a balance beam, shuttle run or hopping sideways on one leg of the BOT2 running speed & agility subtest.

As for the population of the BP group, the fact that some of these children have learning disorders may have reduced the intervention effects. Co-morbidity such as ADHD or PDD-NOS may bring a limited attention span and cause poor motor performance once the tasks become complex and require divided attention, indicating a lack of automatization of the primary task. In our study, all motor and Wii Fit ski slalom tasks were studied in a structured setting. Whether the motor tasks in a child's daily life also show improvement from the intervention is an open question at this moment. Parent interviews and questionnaires may be considered in future studies.

Conclusion

Results of this study show that children with DCD and balance problems are less proficient in playing exergames in which dynamic balance control is needed, compared with children with typical balance skills. Training with the Wii Fit consistently improved motor balance items of the MABC2 and BOT2. The improvements after the intervention were significantly larger or almost significantly larger in motor test results, than changes due to normal development or test–retest effect. For the Wii Fit ski slalom scores improvement was significant and equally large over the non-intervention and the intervention period. Most children maintained their motivation to participate over a period of 6 weeks, that is typical for intervention in children with motor problems.

Competing interest

The authors declare that they have no competing interests.

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