Full Length Article

The effect of exergames on functional strength, anaerobic fitness, balance and agility in children with and without motor coordination difficulties living in low-income communities

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ABSTRACT

Children with Developmental Coordination Disorder (DCD) are physically less active, preferring more sedentary behavior and are at risk of developing health problems or becoming overweight. 18 children (age 6–10 years) with lower levels of motor coordination attending a primary school in a low-income community in South Africa (score on Movement Assessment Battery for Children Second edition equal to or below the 5th percentile) were selected to participate in the study and were age-matched with typically developing peers (TD). Both groups of children engaged in 20 min of active Nintendo Wii Fit gaming on the balance board, twice a week for a period of five weeks. All children were tested before and after the intervention using the lower limb items of the Functional Strength Measurement, the 5×10 meter sprint test, the 5×10 meter slalom sprint test, and the Balance, Running speed and Agility subtest of the Bruininks Oseretsky Test of Motor Proficiency 2nd edition (BOT-2).

After intervention, both groups of children improved in functional strength and anaerobic fitness. The magnitude of these changes was not related to participant's motor coordination level. However, differences in change between the TD and DCD group were apparent on the motor performance tests; children with DCD seemed to benefit more in balance skills of the BOT-2, while the TD children improved more in the Running speed and Agility component of the BOT-2. Compliance to the study protocol over 5 weeks was high and the effect on physical functioning was shown on standardized measures of physical performance validated for children with and without DCD.

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1. Introduction

Until recently, the problem of low levels of physical activity and obesity has largely been limited to more developed, industrialized countries. However, this is no longer the case. Statistics indicate that 50% of learners from low-and middle-income settings in, South Africa, lack the required levels of physical activity (Reddy et al., 2008), with only 7% of girls said to be engaging in recommended levels of physical activity levels (Cole, Bellizi, Flegal & Dietz, 2000). Moreover, South Africa has amongst the highest child obesity rates in Africa with a combined overweight/obesity prevalence of 17% (Warburton, Nicol, & Bredin, 2006; Gordon-Larsen, Nelson, & Popkin, 2004).

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Besides obesity being a major concern in typically developing (TD) children, this problem becomes even greater for children with disabilities, who are reported to have a higher prevalence of obesity (38%) compared to children without disabilities (CDC, 2014). Deficits in motor competence among children with Developmental Coordination Disorder (DCD) make them less likely to participate in active physical free play, in organized sport and physical activities, resulting in low fitness levels and higher levels of obesity in this group regardless of context (Cantell, Crawford, & Tish Doyle-Baker, 2008; Hands & Larkin, 2006; Yu et al., 2016). Poor motor development may result in children not taking part in physical activity, because they do not have the fundamental movement skills required to do so (Ferguson, Aertssen, Rameckers, Jelsma, & Smits-Engelsman, 2014). Many children with motor coordination difficulties also feel embarrassed by their poor performance and subsequently withdraw from physical activities leading to decreased fitness levels (e.g. cardiorespiratory fitness, body composition, muscular strength, muscular endurance, agility, coordination and flexibility). Ultimately, not participating in physical activity has a further negative impact on the motor skill development, resulting in a vicious cycle (Cairney, Hay, Faught, Wade et al., 2005; Cairney, Hay, Faught, & Hawes, 2005).

Engaging in regular physical activity is widely accepted as an effective preventative measure for a variety of health risk factors for children (Janssen & Leblanc, 2010; Pienaar, 2015). Numerous strategies have been designed to increase physical activity levels among children in South Africa (Kinsman et al., 2015; Villiers et al., 2015; Jemmott et al., 2011), however barriers to the promotion of physical activities in schools situated in low-income communities include resource constraints (limited physical education (PE) classes, no sports facilities) and environmental challenges (safety) (Puoane & Mciza, 2009). Finding effective and fun interventions to increase physical activity levels and physical functioning is therefore warranted.

Historically, physical inactivity was considered as one of the primary predictors of low fitness levels. However, recent studies have cited motor competence and perceived motor competence (Castelli & Valley, 2007) as other possible compounding variables (McKenzie et al., 2002; Okely, Booth, & Chey, 2004; Stodden et al., 2008). Physical fitness of children is the ability of the body to function effectively and efficiently without becoming exhausted during daily activities, while performing skills such as running, climbing, jumping. Besides coordination, strength, power or endurance are needed in the development of fitness (Saakslahti et al., 1999; Hands & Larkin, 2006).

Despite the evidence supporting the association between lower levels of motor coordination and physical fitness, there is limited research regarding interventions focusing on these relationships. Importantly, none have directly studied the effect of exergames on both coordination, strength and anaerobic fitness in groups of children with and without motor difficulties. Moreover, studies of this specific nature have not been conducted in low-income settings where opportunities for PE and sports to improve physical activity are limited.

The application of active computer games (exergames) that incorporate virtual reality in pediatric rehabilitation is relatively new. During exergaming, children use significantly more energy than during traditional sedentary computer activities. However, evidence is mixed on whether these games engage children in levels of activity that are consistent with public health recommendations for physical activity and improving cardiorespiratory fitness (Daley, 2009; Draper et al., 2010). In a recent review, Sween et al. (2014) reported that the majority of active videogames tested, were found to achieve physical activity levels of moderate intensity, which meet the American College of Sports Medicine guidelines for health and fitness (Sween et al., 2014). Therefore, exergaming could be attractive to help children with low levels of physical activity to displace sedentary behavior and their use could capitalize on children's motivation to play games.

Exergames may have an additional advantage for children with DCD. Active video games, such as the Wii Fit, which provides immediate feedback to the player, have been shown to improve motor skills and motivation to exercise in various populations including children with developmental coordination disorders (Jelsma, Geuze, Mombarg, & Smits-Engelsman, 2014; Ferguson, Jelsma, Jelsma, & Smits-Engelsman, 2013). These aspects are particularly important in the current context for poor motor control and compliance to exercise programs, since it has been recommended to combine the training of fundamental motor skills with training to increase levels of physical activity in children with DCD and to ensure that rehabilitation programs are enjoyable (Jelsma et al., 2014; Ferguson et al., 2013; Farhat et al., 2015). Everyday physical playground games, sport and other leisure activities require sufficient proficiency in motor control and fitness. Games such as tag, for example combine balance, agility and coordination with anaerobic fitness. If the skills needed to take part in these activities are not trained, the intervention, even if it showed gains in physical fitness, is likely to be ineffective after the training is stopped, since no transfer will take place to those activities. In addition, if the training is not fun and enjoyable, the likelihood that children will comply long enough to see changes in fitness levels will be poorer.

Exergaming provides a relatively low cost way to get children to move and be physically active. If the intended interventions are effective and safe, it would make it ideal for children living in situations where there are significant environmental barriers to exercise participation as the training programs can be set up in safe indoor spaces and no expensive supervision is needed. Exergaming may even increase compliance since many children have never played these types of computer games before. Although the Wii Fit has been shown to improve motor skills in South African children attending a low-income school with DCD and cerebral palsy, to date (Ferguson et al., 2013; Jelsma, Ferguson, Smits-Engelsman, & Geuze, 2015), there are limited published data comparing the impact of Wii Fit on physical fitness in typically developing children and children with DCD living in poor socioeconomic circumstances.

Therefore the primary purpose of this study was to establish if a 5-week training program using Wii Fit games has a positive impact on physical fitness (functional strength, anaerobic fitness, balance, and agility) in a group of children (age 6–10 years) attending school in a low-income community with fewer opportunities to participate in PE and sports. The second purpose was to determine whether the level of motor coordination had an impact on the training effect of physical

fitness outcomes. We expected the study to demonstrate the efficacy of Wii interventions on physical fitness (functional strength, anaerobic fitness, balance, and agility).

2. Methods

2.1. Research design

A pre-post experimental design was used to evaluate changes in functional strength, anaerobic fitness, balance and agility after 5 weeks of Wii training in children with and without DCD.

2.2. Participants

To select participants, we used the same procedure as described in earlier studies (Ferguson, Jelsma, Jelsma, Smits-Engelsman, 2014; Ferguson, Naidoo, & Smits-Engelsman, 2015). Teachers and parents were asked to assist in identifying children with motor coordination problems based on their observation of the children in class and on the playground by highlighting the child's name on a class roster (teacher) or completing a questionnaire enquiring about the child's functional motor skills at home (parents) and returning this information to the researchers.

The four *DSM-5* criteria were then used to identify children with DCD (American Psychiatric Association, 2013). All children who scored below the 5th percentile on the Movement Assessment Battery for Children 2nd edition (Criterion A), who were identified as having a motor coordination problem by the teacher or parent (Criterion B), whose parents reported no diagnosis of a significant medical condition known to affect motor performance in the parental questionnaire (Criterion C); and whose teacher affirmed the absence of intellectual or cognitive impairment (Criterion D) appeared to fulfill the criteria for DCD. Through this procedure, 18 children between 6 and 10 years of age were selected to take part in the study and they were age-matched with TD children from the same classes.

Typically developing children had: 1) no evidence of functional motor problems as observed by their teacher or parent, 2) a score above the 16th percentile on the MABC-2, 3) no diagnosis of a significant medical condition as reported by a parent and 4) absence of intellectual or cognitive impairment as reported by their teacher.

2.3. Instruments

2.3.1. The Movement Assessment Battery for Children-2 (MABC-2)

The MABC-2 (Henderson, Sugden, & Barnett, 2007) was used as pretest to confirm that motor skills were below expected level for the age of the child. It consists of eight physical subtests used to assess motor coordination in children aged 3–16 years. Raw scores for each item are converted into standard scores. The Total Standard Score (TSS) is a sum of the individual standard scores and gives an impression of overall motor proficiency. The MABC-2 is considered a reliable and valid measure to assess motor performance. In children with DCD, internal consistency is reported to be high (alpha = 0.90) and test-retest reliability for the total scores is regarded as excellent (ICC = 0.97) (Henderson et al., 2007; Smits-Engelsman, 2010; Wuang, Su, & Su, 2012).

2.3.2. Lower extremity items of the Functional Strength Measure (FSM)

The Functional Strength Measure was used to assess functional strength (Aertssen, Ferguson & Smits-Engelsman, 2015). The FSM measures muscular endurance and power across eight functional activities. For this study the lower extremity items were used; Long jump, Lateral step-up, Sit to stand and Stair climbing (see Fig. 1). Each test has three trials and the best raw scores were used for reporting in this study. Reliability of the FSM is reported in the manual with ICC's for the various items ranging from, 0.73 to 0.91 (Smits-Engelsman & Verhoef-Aertssen, 2012).

2.3.3. Anaerobic fitness: 10×5 meter sprint and 10×5 meter slalom

Sprinting tests were used to assess anaerobic capacity. In the 10×5-meter sprint test children have to run a distance of 5 m ten times without stopping (Mechelen, Lier, & Hlobil, 1991; Bovend'eerdt, Kemper, & Verschuur, 1980). After every 5 m the child has to turn. The time to complete the 10 laps (measured in seconds) is recorded. The test has good reliability in TD children (Mechelen et al., 1991; Bovend'eerdt et al., 1980) and excellent interobserver reliability (intraclass correlation [ICC] = 1.0 and ICC ⩾ 0.97) and test−retest reliability (ICC = 0.97 and ICC ⩾ 0.97) in children classified with milder forms of cerebral palsy (GMFCS level I and level II) (Verschuren, Takken, Ketelaar, Gorter, & Helders, 2007). So far, it is known that after practicing Wii Fit balance games children anticipate better and react faster, resulting in faster changes of direction during tasks like hopping or jumping sideways (Hammond, Jones, Hill, Green, & Male, 2014; Jelsma et al., 2014). We expect this effect to be accentuated in 10×5 m sprint tests and the 10×5-meter slalom test.

The 10×5-meter slalom sprint test is a newly developed test for the purpose of this study, which requires higher levels of agility. It has a similar protocol to the 10×5 m sprint test, but the trajectory that the children have to run is curved and requires a number of directional changes to be made (Fig. 1).

Lateral step-up
Touch the floor as fast as possible. Count the number of repetitions in 30 seconds.

Standing long jump
Jump forwards as far as possible. Measure the distance in centimetres.

Sit to stand
Stand up and sit down as quickly as possible. Count the number of repetitions in 30 seconds.

Stair climbing
Climbing up and down stairs as quickly as possible. Count the number of steps in 30 seconds.

10x5 meter sprint
Track distance is 5 meter. Run 10 times 5 meter without stopping. Time in milliseconds is measured

10x5 meter slalom sprint
Track distance is 5 meter. Strait start to stop line is 4.41meter (a). Run 10 times without stopping. Time in milliseconds is measured

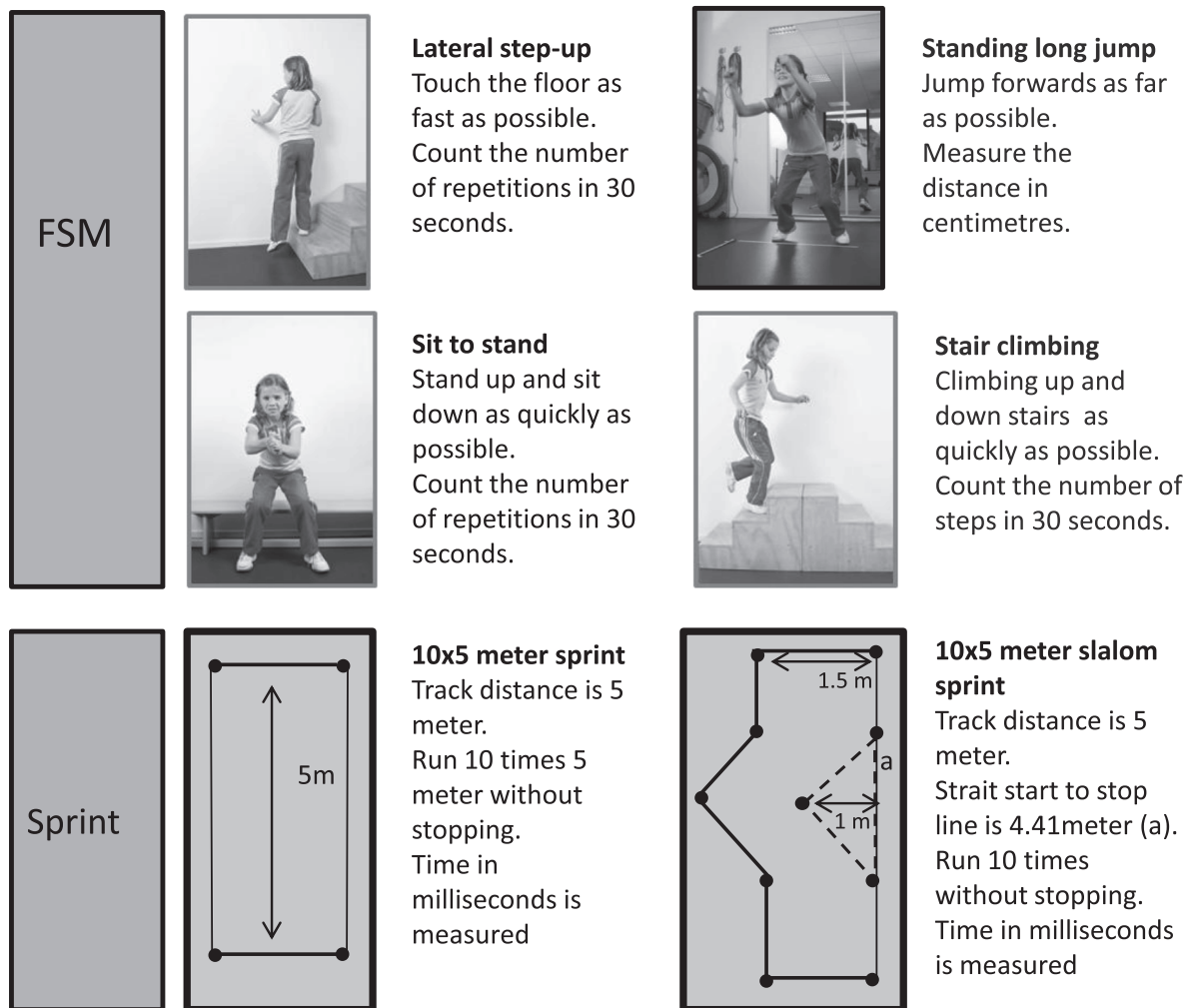FSM

Sprint

5m

1.5 m

1 m

a

Fig. 1. Pictures and descriptions of the lower extremity items of the FSM and the sprint tests.

2.3.4. Balance and Running speed & Agility subtests of the Bruininks Oseretsky test of motor proficiency 2 (BOT2)

All children were tested on two subtests of the Bruininks Oseretsky Test of Motor Proficiency, second edition (Bruininks & Bruininks, 2005). The subtest Balance consists of seven static balance tasks and two dynamic balance tasks. The subtest Running speed & Agility consists of one sprint task and four agility 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, which were used for the analysis. Inter-rater reliability for scale scores is consistently high for subtest Balance (0.99), and Running speed & Agility (0.99) (Bruininks & Bruininks, 2005).

2.3.5. Enjoyment rating scale

Because motivation might be related to the level of motor proficiency we included an enjoyment rating scale to measure the level of enjoyment experienced by the participants during the intervention. Children chose from five different smiley faces to rate their gaming experience (0 is "no fun at all"; 1 is "boring", 2 is "a bit of fun", 3 is "fun" and 4 is "super fun"), using a scale that was developed for one of our earlier studies (Jelsma et al., 2014). We evaluated how much the child enjoyed playing Wii games on three occasions (after the first week, after 3 weeks and after the last session).

2.4. Procedure

The University of Cape Town, Faculty of Health Sciences Human Research Ethics committee and the designated educational authorities granted approval for the study (HREC: 556/2014). Informed consent was obtained from all parents and informed assent was obtained from each child. Children with DCD were tested by a team of qualified physiotherapists and physiotherapy students who had received additional training on the administration of all outcome measures prior to

commencement of the study. Children, who met the inclusion criteria for the study, were also tested on the FSM and BOT-2 on the same day, but performed the 10×5 m sprint tests on another day. Intervention commenced one week later and continued for five weeks. All pre- and post measures were conducted by two separate teams of assessors, who were blinded to the pretest outcomes.

2.4.1. Intervention

Four television monitors and four off-the-shelf Nintendo Wii motion-controlled video consoles (Nintendo Co. Ltd., Kyoto, Japan), including the balance boards, were set up in an unused room on the school premises. While standing on the balance board, a child can steer the virtual character (Mii) of the game by shifting weight in lateral or anterior-posterior direction, walking on the spot or bending and extending the knees in order to virtually jump.

Four children participated simultaneously on the systems under the supervision and guidance of two trained student therapists. All television screens were separated by partitions to ensure that the children concentrated on their own screen. The role of the student therapists during training was to instruct, encourage and motivate the children, document the choice of games played and record the time the children were actively playing the game. Children engaged in 20 min of active gaming on the balance board, twice a week for a period of five weeks. Each training session comprised of a self-selected choice out of ten games, which were specifically selected to target the goals of this study (functional strength, anaerobic fitness, balance skills and agility). Children could decide to play the same game twice in a session if they wanted. If children missed a training session, they were offered an opportunity to attend a catch-up session, preferably in the same week, or during an extra session in the next week. All children in the study completed 10 training sessions.

2.5. Data analysis

All data were checked for normality and equality of variances and appropriate parametric or non-parametric analyses were performed. Differences in demographic characteristics between the groups were calculated at baseline using Pearson's Chi squared test (sex and handedness) or *t*-test (age, BMI).

First we counted the number of different games played by the children and tested if the frequency of the games chosen was different between groups, to evaluate if children with DCD or TD preferred to play certain games more often than others, as this might have lead to a different kind of training for the two groups.

Next we tested if functional strength, anaerobic fitness, balance and agility changed with training and if this effect was different between groups, by using a repeated measure ANOVA with pre and post score as within group factors and group as between factor.

Cohen's d effect sizes were calculated to determine the between-group effects (interpretation: >0.20 = small, >0.50 = moderate and >0.80 = large effect size (Cohen, 1977)) and partial eta squared η^2 for the within-group and between-group effects (interpretation: 0.01–0.05 = small effect; 0.06–0.14 = medium effect; and $\geqslant 0.14$ = large effect (Field, 2010)).

Lastly, post hoc paired t-tests were done to compare pre-and post values for the TD and DCD group separately, if a group by training interaction was found.

Significance level was set at $p < 0.05$. All statistical analyses were run in Statistical Package for the Social Sciences (SPSS Inc., version 23).

3. Results

3.1. Group differences at baseline

One child with DCD fell ill at the very beginning of the training and was excluded from the study. No group differences were found with regards to age (mean age: DCD 8.2(1.13) and TD 8.0(1.22) years, range 6–10), or gender (boys: girls; DCD 9:8 TD 9:9), hand preference (1 left handed child in each group). There was a trend for the children with DCD to have higher weight (DCD 33.75 (11.15), TD 28.28(6.16) (t = 1.78, df = 33, p = 0.09) and higher BMI (DCD 18.88 (4.55), TD 16.40(2.61) (t = 1.99, df = 33, p = 0.055). Four obese children in the DCD group caused this large variance, while there was 1 child classified as obese in the TD group. As expected, the MABC-2 total standard score was different (t = 12.41, df 33, p < 0.0001, mean TD 11.22 (2.10) DCD 3.77(1.35)) (see Table 1 for baseline characteristics per group).

In agreement with the literature, children with DCD scored considerably worse on all physical fitness measures, with large effect sizes, except for the sprint tests, which only showed a trend for difference between groups (see Table 1 for effect sizes and Table 2 for means per group).

3.2. Games played

Both groups played the same number of games per training session (DCD 7.1 (SD = 1.3), TD 7.1(SD = 1.4)). The children chose all 10 games but there were clear favorites (Fig. 2). Obstacle Course, Ski Jump and Kung Fu were chosen most often, however Ski Jump and Balance Bubble were the only games that the children liked to play twice during the same session. The

Table 1
Statistical comparison (independent t-test) between groups at baseline on Strength, Sprint, Balance and Agility for DCD (n = 17) and TD (n = 18) groups.

Variables	t (df = 33)	P value	Cohen d
Long Jump (cm)	−2.97	<0.01	1.03
Lateral step up Right (#)	−2.45	0.02	0.83
Lateral step up Left (#)	−2.88	<0.01	0.97
Sit to stand (#)	−3.06	<0.01	1.03
Stairs (#)	−2.79	<0.01	0.95
Sprint[a] (s)	2.00	0.05	−0.66
Sprint slalom[a] (s)	1.82	0.08	−0.60
BOT-2[b] Balance	5.79	<0.001	1.90
BOT-2[b] Agility	3.25	<0.01	1.09
MABC-2 TSS[c]	−12.41	<0.001	4.19
MABC-2 Manual Dexterity	−6.78	<0.001	2.30
MABC-2 Aiming and Catching	−5.74	<0.001	1.94
MABC-2 Balance	−8.18	<0.001	2.77

[a] Data from 1 child in the DCD group were missing.
[b] BOT-2: Bruininks Oseretsky Test second edition.
[c] MABC-2: Movement Assessment Battery for Children second edition.

Table 2
The effect of Wii Training on Strength, Sprint, Balance and Agility. Means and SD per group for pre and post values and effect sizes (Cohen D) of the change within group.

Paired samples statistics	DCD n = 17					TD n = 18				
	Pre		Post		Cohen D	Pre		Post		Cohen D
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Long jump (cm)	96.9	19.4	110.5	16.5	−0.8	115.3	17.2	133.1	17.5	−1.6
Lateral step up Right (#)	29.5	5.0	43.7	9.1	−2.0	33.1	3.6	47.1	7.6	−3.3
Lateral step up Left (#)	29.4	5.6	45.9	9.6	−2.2	34.2	4.2	46.4	7.5	−2.7
Sit to stand (#)	19.4	4.1	35.5	4.1	−3.9	24.4	5.5	38.7	5.8	−2.8
Stairs (#)	64.5	7.9	76.5	10.1	−1.3	74.1	11.8	80.2	19.0	−0.7
Sprint [a] (sec)	26.6	5.1	23.9	2.5	0.7	24.0	2.3	21.9	1.8	0.6
Sprint slalom [a] (sec)	35.3	6.1	25.0	3.1	2.2	32.2	4.1	22.1	2.0	2.3
BOT-2 [b] Balance	13.8	3.0	17.7	4.9	−1.0	20.1	3.6	21.2	2.3	−0.3
BOT-2 [b] Agility	17.9	3.4	18.6	4.1	−0.2	21.0	2.2	24.3	2.3	−0.9

[a] Data from 1 child in the DCD group were missing.
[b] Bruininks Oseretsky Test second edition.
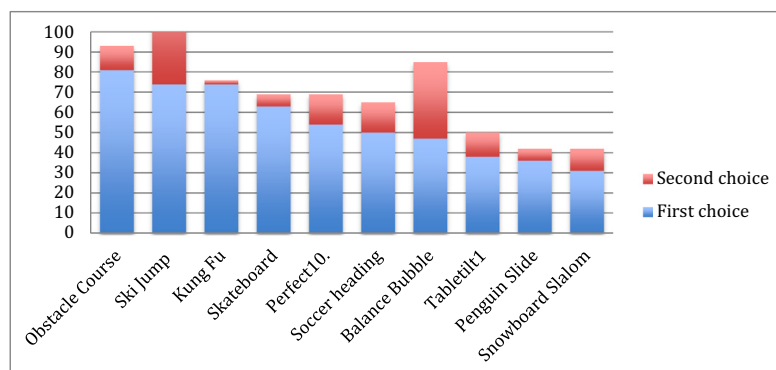
Fig. 2. Percentage of chosen games during intervention once or twice.

frequency of the chosen games was only different for 2 out of the 10 games. The children with DCD had a preference for Soccer Heading (Chi = 6.6, df 1, p = 0.014; 57% of the choices by DCD and 43% TD) while TD children preferred playing Balance Bubble (Chi = 14.2, df 1, p = 0.001; 36% DCD and 57% TD).

3.3. Enjoyment rating scale

After the first week, 32 children reported the training to be "super fun", two children rated the training as "fun" (1 DCD and 1 TD) and one child rated the training as "a bit of fun" (DCD). After five weeks, 34 children rated the training as "super fun" (16 DCD, 18 TD) and 1 as "fun" (DCD).

3.4. Functional strength

Actively playing self-chosen Wii games 20 min per training session had a large effect (Table 2) on functional strength in both groups of children, even though their starting level was different (see Table 1). The main effect of training was significant for all the items and no interaction with groups arose (Table 3). So both groups seemed to benefit comparably. Post hoc test comparing pre and post per group (Table 4) showed that children improved significantly on all items except the TD group on the item stairs, though this difference in change did not lead to a significant interaction effect.

3.5. Anaerobic fitness

After the training, in which the children were engaged in short bursts of activity achieved while interacting with the Mii on the screen, significant changes in anaerobic performance as measured by the 10×5 meter sprint test, were found. This effect was even more pronounced if many changes in movement direction had to be made (sprint slalom). The main effect of training was significant for both items and no interaction with groups occurred (Tables 3 and 4). After the training, the children ran the slalom track close to 30% faster.

3.6. BOT-2

A different picture emerged on the BOT-2. The main effect of training was significant on both subtests with a significant interaction between group and training (Table 3). The children with DCD improved significantly on the subtest balance of the BOT-2 (Table 4), while there was no change in the TD group. The balance items (standing feet apart on a line, walking forward on a line, standing on 1 leg with eyes open and closed on a line and on a balance beam, standing heel to toe on a balance beam) have a maximum score if the child can do the task for 10 s. This led to almost perfect scores for the TD group (TD children had maximum scores on 5 items) who only showed minor difficulties when standing on one leg on the balance beam, giving rise to the possibility of improvement.

Table 3
Repeated measure outcomes of group, training and the interaction group by training on strength, agility and balance.

Variables	Group			Training			Interaction training $\times$ group		
	F [1,33]	Partial η^2	P value	F [1,33]	Partial η^2	P value	F [1,33]	Partial η^2	P value
Long Jump (cm)	13,99	0.30	0.001	42.06	0.56	<0.001	0.757	0.02	0.390
Lateral step up Right (#)	4.02	0.11	0.053	95.56	0.74	<0.001	0.007	0.00	0.936
Lateral step up Left (#)	1.95	0.06	0.172	101.16	0.75	<0.001	2.32	0.07	0.137
Sit to stand (#)	11.08	0.25	0.002	179.45	0.85	<0.001	0.66	0.02	0.423
Stairs (#)	3.70	0.10	0.063	11.13	0.25	0.002	1.15	0.03	0.292
Sprint[a] (sec)	6.15	0.16	0.019	15.51	0.33	<0.001	0.26	0.008	0.616
Sprint slalom[a] (sec)	6.21	0.16	0.018	200.91	0.86	<0.001	0.15	0.00	0.903
BOT-2[b] Balance	24.50	0.42	<0.001	14.25	0.30	0.001	4.47	0.12	0.042
BOT-2 [b] Agility	20.35	0.27	0.001	28.77	0.47	<0.001	11.99	0.27	0.001

[a] Data from 1 child in the DCD group were missing.
[b] Bruininks Oseretsky Test second edition.

Table 4
Post hoc comparison between means (SD) pre and post test on Strength, Sprint, Balance and Agility scores for DCD (n = 17) and TD (n = 18) group.

Variables	DCD		TD	
	t (df = 16)	P value	t (df = 17)	P value
Long jump (cm)	−3.30	0.005	−6.72	0.0001
Lateral Step Up Right (#)	−6.41	0.0001	−7.52	0.0001
Lateral Step up Left (#)	−7.32	0.0001	−6.87	0.0001
Sit to stand (#)	−10.51	0.0001	−8.59	0.0001
Stairs (#)	−7.03	0.0001	−1.22	0.24
Sprint (sec)	2.36	0.03	5.15	0.0001
Sprint slalom (sec)	8.59	0.0001	12.66	0.0001
BOT-2 Balance[a]	−3.02[B]	0.003	−1.34 [b]	0.18
BOT-2 Agility	−1.54	0.14	−5.69	0.0001

[a] Wilcoxon Rank test was used because of non-normal distribution.
[b] z-value.

In contrast, the range of scores in the Running speed and Agility items had no maximum scores for the all children. The change on the Running speed & Agility items (dash sprint time for 2×50 feet, number of side steps over a balance beam (15 s), one legged stationary hop (15 s), one legged side hop (15 s), and two legged side hop (15 s), was significant in the TD children but not in the children with DCD (for statistics see Table 4).

4. Discussion

Various studies report that children with DCD have lower physical fitness levels compared to typically developing children (Magelhaes, Cardoso, & Missiuna, 2011; Rivilis et al., 2011; van der Hoek et al., 2012; Ferguson et al., 2014). This finding was confirmed in our study in a population of children with DCD, where we observed poorer performance in functional strength, agility and a trend in lower performance on sprint tests (effect sizes between 0.60 and 1.09).

The purpose of this study was to evaluate the efficacy of Wii Fit intervention aimed at improving motor performance and increasing fitness levels in children with limited opportunities to participate in sports, structured PE classes, and outdoor play. Studies investigating the use of exergames claim that this technology, improves not only motor performance but also motivation to exercise (Green & Wilson, 2012; Levac & Miller, 2013; Jelsma et al., 2014). We determined the changes in functional strength, anaerobic fitness, balance and agility of TD and DCD children over a 5-week period of Wii training with a voluntary choice of games. The games played required balance, coordination, anaerobic endurance, strength and lower extremity control. It seemed that these components of the Wii Fit games had a beneficial effect on both the muscular endurance and the neuromuscular components (control of dynamic balance and agility). The effect of Wii training on balance skills has been shown in other groups of children in earlier studies (Barnett, Hinkley, Okely, Hesketh, & Salmon, 2012; Hammond et al., 2014; Jelsma, Geuze, Mombarg, & Smits-Engelsman, 2014; Mombarg, Jelsma, & Hartman, 2013) and was again clear in the present group of children with DCD. New findings from this study were the large effects (partial $\eta^2 = 0.30$–0.86) on functional strength, anaerobic fitness and agility. Apparently, practicing numerous timed weight shifts in opposing directions resulted in faster turnabouts needed in the 10×5 meter sprint test, as well as faster reversal movements in the items stairs and sit-to-stand.

Learned non-use may be one of the factors associated with physical activity differences between older children with and without DCD. Reduced physical activity levels of older children may be associated with withdrawal from physical activity that they previously engaged in due to negative experiences or frustration after not coping with the task. We propose that by using a *novel* task, the child's performance is mostly determined by internal factors that impact on motor proficiency, which is lower in children with DCD. Since children were novice to the task, the course of skill development has not yet been influenced by the negative feedback obtained through interaction with peers so they may still feel positively motivated to try it out.

By giving the children a choice of games, we facilitated improvement and compliance as free choice during or before practice enhances learning of a skill due to the notion of satisfying the learner's need for autonomy (Lewthwaite, Chiviacowsky, Drews, & Wulf, 2015). The only restriction was that they could not play the same game more than twice within one session. Especially in DCD, allowing participants to make choices about which game they would like to play is seen as an advantage as it decreases resistance, and lessens anxious responses, laying the groundwork for better engagement in physical activity. No differences in enjoyment between groups or between the beginning and end of the training were seen in this study, even though the performance on the games was lower in the children with DCD.

Considerable research supports the motor-learning advantage associated with an external focus of attention over internal focus (Wulf et al., 2016; Wulf, Shea, & Lewthwaite, 2010). Motion steered skill training is by definition based on external focus. In a traditional therapy model of intervention, a therapist provides feedback on skill execution that is based upon the learner's prior performance. However, in exergaming, the computer and not the therapist gives visual and auditory information to learners about current (real-time) skill execution. The computer feedback gives immediate knowledge of performance aiming to help learners reduce errors, correct them more quickly, and bring their movement patterns closer to the goal of the game and improve the personal best score. So by its nature, all exergames share principles of implicit learning and our training time provided ample practice opportunities using many games with positive reinforcement through visual and auditory feedback.

Skilled motor performance requires the effective and efficient gathering of sensory information. During exergaming, children have to take in and process multiple forms of sensory information from the computer, decide where and when to look on the screen, and thus an important component of game training may involve learning of how to extract task-relevant information. In all games, the avatar responds immediately to shifts of the child's center of pressure as they move in different directions. This can be considered as a form of augmented feedback. Information about the changes in center of pressure through the weight shifts on the balance board may help the child to make a kinesthetic and visuo-motor coupling and to link these changes to the fine tuning of forces and torques generated. This could explain why children with DCD improved on balance items with eyes closed (BOT-2), even though they never had their eyes closed during the training.

In everyday life, we have to use predictive as well as reactive control mechanisms to generate appropriate motor commands to achieve the task goals. It might be that looking at an avatar is an indirect form of action observation treatment which uses "self-observation", to enhance balance control and motor skill acquisition, due to the reorganization of motor representations at a central level (Buccino, 2014). By steering the avatar over the course of the training, the children (with

DCD) may learn to make a comparison between the predicted movement based on their weight shift and actual displacement of the Mii. In this way, they learn to fine-tune their internal model of the movements practiced. Most games used in this study incorporated timed, full body movements, which might have helped children to learn these aspects of anticipatory in postural control. It is possible that the extensive training of timing, so important in exergames, transfers to other activities and makes the children more agile, partly because it can better anticipate changes in direction leading to faster slalom times and stair runs. In addition standing on the balance board with slightly flexed knees, making explosive stretching movements, and shifting weight for 20 min per session, necessitates lower limb stability. This will lead to increased muscular endurance and power of the lower extremity, as confirmed by an increased number of sit to stands (FSM) and increased distance in the long jump (FSM).

The two interaction effects found in the present study have different origins, but both relate to the item difficulty. The fact that TD children improved less on the BOT-2 Balance items is clearly due to the ceiling effect of the measure. However, improvement on BOT balance like standing on one leg or standing on a narrow beam, for the DCD group may be a clinically important change for participation in recreational games and sport and may enable them to take part in playground activities. The other interaction effect, i.e. the difference in improvement on BOT-2 Running speed and Agility sub test, may have been caused by the higher level of difficulty of these items. The TD children showed large improvements on the items one- and two-legged side hop. These items were still difficult for the children with DCD after the training who only managed to improve on simple balance items.

Our study results suggest that children's physical functioning improved and that they liked playing these active games. This was also the case for individuals of lower motor proficiency, who usually do not like fitness training, (Cermak et al., 2015; Cairney, Hay, Faught, Wade et al., 2005; Engel-Yeger & Kasis, 2010).

It seems that this group could benefit from the motivation and feedback that exergaming provides. The fact that they enjoy playing these games could be a large advantage for compliance. A child with relatively low movement proficiency appears to be rewarded enough to keep playing even if the resulting game score does not achieve the levels of a proficient child. Since we found only interaction effects on the motor performance test (predominantly items including balance) it would appear that the training does not seem to be closing the gap in physical fitness between the individuals in the two groups. Both groups improved equally on functional strength and anaerobic fitness. Further studies are needed to determine if this pattern of comparable improvement would remain over a longer study period. It is also worth exploring if exergames could be adapted per individual to comply with strength and conditioning guidelines of the American College of Sports Medicine (Garber et al., 2011).

5. Limitations

We were not able to evaluate the level of physical activity of the children directly, however none of the children participated in formal organized sports and all children had very limited exposure to PE classes. Furthermore, the group of children participating in this study was heterogeneous regarding level of motor skills, which may limit the internal validity but contributes to external validity.

Both groups of children received the same intervention, which is a strong point of the study design. For future studies it is highly recommended to add a group receiving a different intervention to rule out test-retest effects and possible other biases not covered in a single blinded case control study.

6. Conclusion

At the start of the study, children with DCD scored considerably worse than their TD counterparts on all physical fitness measures, except for the sprint tests which only showed a trend for difference between groups. Active gaming improved functional strength and anaerobic fitness in both groups. Additionally, training lead to better balance skills in children with DCD, while the TD children improved in the agility items of the BOT-2. Compliance to the study protocol over 5 weeks was high and the effect on physical functioning was shown on standardized measures of physical performance validated for children with and without DCD. We conclude that active video games can be used to achieve safe and enjoyable physical exercise in children with and without DCD to improve their physical fitness.

Competing interest

The authors declare that they have no competing interests.

Acknowledgments

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