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Title: An active video game intervention does not improve physical activity and sedentary time of children at-risk for developmental coordination disorder: a crossover randomized trial

Running title: Active video games for children with DCD

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Abstract

Background Children with developmental coordination disorder (DCD) are highly inactive and sedentary. The purpose of this study was to assess the impact of a home-based active video game intervention on objectively measured physical activity and sedentary behaviour in children at-risk for DCD.

Methods In a crossover randomized clinical trial, 21 children (mean age 11.0, SD 1.0; n=11 females) in Perth, Western Australia participated in two 16-week periods: no active video games (AVGs) control period and active video games intervention period. Two active input consoles were provided to participants along with a selection of non-violent AVGs for participants to play at home. Participants wore accelerometers at baseline and following each period to determine minutes of sedentary, light, moderate and vigorous time in addition self-reported types of activities in a diary. Linear mixed models, adjusted for the order of periods, compared physical activity and sedentary time during the last week of each period.

Results There were no significant differences between the intervention and control periods in time spent in sedentary (decrease of -1.0 minutes per day during the intervention period, 95%CI: -12.1, 10.1), light (increase of 2.2 minutes per day, 95%CI: -8.8, 13.2), moderate (decrease of 0.7 minutes per day, 95%CI -4.6, 3.3) or vigorous (decrease of -0.6 minutes per day, 95%CI: -1.6, 0.4).

Conclusions Among children at-risk for DCD, participating in this AVG intervention did not improve objectively measured physical activity and sedentary time.

Abbreviations Developmental coordination disorder (DCD), active video games (AVG).

Key Messages

- There were no differences in physical activity or sedentary time during an active video game intervention among children at-risk for DCD.
- Children reported more physical activity but less outdoor play during the active video game intervention compared to the control period.
- Unsupervised home use of active video games is not a recommended tool for increasing physical activity among children at-risk for DCD.

Introduction

Developmental coordination disorder (DCD) affects a large number of children with population estimates ranging from 1.4% to 19% (Zwicker *et al.* 2012). DCD is a common developmental disorder characterized by difficulties in performing everyday motor skills that are not attributed to another physical, sensory or intellectual impairment (Wilson and Crawford 2007). Beyond poor motor skill performance, children with DCD suffer disproportionately from other health issues including depression, mental difficulties (Lingam *et al.* 2012), poor fitness, and obesity (Hendrix *et al.* 2014, Rivilis *et al.* 2011).

Additionally, children with DCD have lower levels of physical activity and higher levels of sedentary behaviour than typically developing children (Beutum *et al.* 2013, Green *et al.* 2011, Rivilis *et al.* 2011). It has been suggested that children with DCD experience additional barriers to physical activity participation compared to typically developing children, such as functional limitations, high costs of specialised programs, and a lack of specialised programs (Shields *et al.* 2012, King *et al.* 2003, Barnett *et al.* 2013). Unfortunately, very few interventions have sought to increase physical activity participation in children with DCD. The majority of interventions for children with DCD have been aimed at improving motor skill, which may contribute to physical activity levels through indirect pathways, however this has rarely been independently assessed (Smits-Engelsman *et al.* 2013). No studies have used objective measures of physical activity to measure response to an intervention for children with DCD.

One type of intervention that might improve physical activity levels, through both direct and/or indirect pathways, is active video games (AVG) (Straker *et al.* 2015b). Active video games have been shown to increase energy expenditure of children in laboratory settings (Smallwood *et al.* 2012, Straker and Abbott 2007) including youth with disabilities (Rowland and Rimmer 2012,

Del Corral *et al.* 2014). Whilst AVGs have not been able to increase objectively measured physical activity in healthy children (Chaput *et al.* 2013, Errikson *et al.* 2012, Baranowski *et al.* 2012, Maddison *et al.* 2011, Straker *et al.* 2013), they may be particularly effective for children with DCD as they would provide high repetition for skill development, are low cost, can be done at home without “judgment” from higher skilled peers, and may increase motivation and engagement (Shields *et al.* 2012, Straker *et al.* 2011).

Specifically, in children with DCD, poor motor coordination may be limiting their participation in physical activity, and AVG interventions in controlled settings have been shown to improve motor coordination in children with DCD (Hammond, et al., 2014; Jelsma, et al., 2013; Salem, et al., 2012). Children with DCD also have reduced motivation and self-efficacy to participate in sports (Batey *et al.* 2013), particularly in social environments (eg school/organized team sports) (Kwan *et al.* 2013). Thus the ability to play AVGs in their own home, without the risk of scrutiny of peers may be beneficial. Children may improve their PA during AVG play, but they may also improve motor coordination and self- efficacy which may improve PA outside of AVGs. Thus AVGs may improve PA through two pathways: direct and indirect (Bufton *et al.* 2014). No studies to date have tested the effect of AVGs on physical activity and sedentary levels in children with DCD.

The purpose of this study was to assess the impact of an AVG intervention on objectively measured physical activity and sedentary behaviour in children with DCD. It was hypothesized that participants would have higher physical activity and lower sedentary time following the AVG intervention.

Methods

Study Design. This study was a cross-over randomised controlled trial. The trial details have been previously published (Straker *et al.* 2015a, Straker *et al.* 2011). In brief, children participated in intervention and control periods between March and November 2011; active video games (AVG) intervention period and no active video games control period. The order of periods was randomized for each child by simple alternating order in sequential recruitment. The duration of each period was 16 weeks. Participants attended data collection at Curtin University prior to study participation (baseline) and at the end of each period for a total of three assessments. The trial was registered with the Australian New Zealand Clinical Trials Registry (Australian New Zealand Clinical Trials Registry #ACTRN12611000400965). The study was approved by the Human Research Ethics Committee of Curtin University (approval number HR11/2011).

Participants. Participants were 21 children between the ages of 10 and 12 years with DCD or at-risk for DCD. They were recruited from the community between February and March 2011. DCD is characterized by both motor impairment and the impact of the impairment (Blank 2012). DCD status was confirmed using the Movement Assessment Battery for Children-Second Version (MABC-2) ($\leq 16^{\text{th}}$ percentile) and Developmental Coordination Disorder Questionnaire (DCDQ) (<total score of 58) according to previous studies (Blank 2012). Children were screened for DCD during an initial visit at the University or at a community setting, by an experienced physical education teacher. The MABC-2 assesses motor impairment in three broad categories of manual dexterity, aiming and catching and balance as well as providing an overall age-standardized score of motor impairment. The original MABC has a high test-retest reliability

(0.75) and inter-rater reliability (0.7) (Henderson S *et al.* 2007). Parents' perceptions of the effect of their child's motor impairment on daily living were quantified using the DCDQ. This questionnaire has previously demonstrated sufficient reliability, validity and sensitivity (Wilson *et al.* 2009). The participants had a mean MABC-2 total score percentile of 5.9 (SD 5.2) with 14 participants with a percentile at the 5th percentile or below (mean MABC-2= 2.8, SD 2.0) and 7 participants between the 5th and 16th percentiles (mean MABC-2=12.0, SD 3.7). The mean DCD-Q score was 32.4 (SD 9.5).

Additionally, children were excluded if they had a diagnosed disorder limiting participation with electronic games, could not maintain access to games or lived remote to the university campus. No children were excluded due to other diagnosed disorders that would limit their participation and all participants were in mainstream school education.

Intervention. During the intervention period, participants were provided with a PlayStation3 (Sony, Tokyo, Japan) with Move and Eye input devices, an Xbox360 (Microsoft, Redmond, USA) with Kinect input devices, and a range of non-violent games to use at home for 16 weeks. An intervention duration of 16 weeks was chosen to provide sufficient time for changes in behaviours and outcomes such as motor skills (Morgan *et al.* 2013) and health improvements from physical activity (Baquet *et al.* 2003), as well to examine longer term maintenance of behaviours after potential initial novelty effects. Children were initially provided with eleven AVGs for both consoles (examples: Kinect Adventures and Start the Party; Eye Pet and Sports Champions) that targeted a variety of gross and fine motor skills and were encouraged by research staff to play a variety of games on both gaming consoles. Approximately halfway through the intervention period, children were provided with two additional games. Children were encouraged to play the AVGs for at least 20 minutes a day on most days of the week (i.e. 4-

5 days) and to regularly select a variety of games covering both gross motor and fine motor skills. Children recorded active video game use in a daily calendar. During the control period, the study active input consoles and games were removed from the homes and participants agreed to avoid AVGs in other settings. They were allowed to play any personal traditional sedentary games during both the intervention and control periods. Research assistants contacted participants every two weeks during both periods to troubleshoot technical issues, monitor AVG exposure, traditional electronic game play, and other physical activities. Participants were provided a \$50 gift voucher to a department store for participation in the study.

Measures

Accelerometry. Participants were instructed to wear Actical accelerometers (Respironics; Bend, Oregon, USA) for one week at baseline and during the last week of each period on their right hip during waking hours, and excluding water-based activities. Data were collected in 15 second epochs. Data were visually inspected and compared with activity diaries to determine daytime wear start and stop times. Accelerometry data were processed using a customised LabView V7® (National Instruments, Austin, TX, USA) program to determine daily minutes of sedentary, light, moderate and vigorous physical activity using device specific intensity cut-points for children (sedentary: <100, light: ≥ 100 -1600, moderate: ≥ 1600 -4760, vigorous: ≥ 4760) (Colley and Tremblay 2011). To be included in the analyses, participants needed 4 days of data (including one weekend day) of a minimum 10 hours per day during the data collection period (Cain *et al.* 2013). Periods of consecutive zeros greater than 120 minutes were considered non-wear time as previous work by the research group has found valid sedentary bouts of greater than 90 minutes. Breaks in sedentary behaviour were defined as at least one minute sequences with counts per minute greater than 100 cpm between bouts of sedentary time and were calculated as mean

breaks per hour of sedentary time. The mean amounts of time spent in bouts of sedentary time between 30 and 60 and greater than 60 minutes without an interruption greater than 100 cpm were calculated. As the after school period was targeted as a key time for active video game play, a separate analysis was performed for the afterschool period (from 3:30 PM to 6:00 PM on schooldays only).

Self-reported activities. To gain a better understanding of the context of physical activities and what activities the AVGs were replacing, participants completed activity diaries for one week at each assessment and recorded the number of minutes in AVGs, traditional electronic games, and physical activities.

Statistical Analysis. Baseline descriptions of total time and percentage of time in each intensity band were calculated for weekends, weekdays, after school periods, and the total day.

Comparisons between types of day were made using repeated measures ANOVA.

Minutes per day in sedentary, light, moderate and vigorous activity were compared between the intervention and control periods using mixed linear models with individual random intercepts for repeated measures within subjects. The number of breaks in sedentary time, bouts of sedentary activity greater than 30 minutes, and minutes per week in self-reported activities were also analysed as dependent outcomes in separate models. A separate time variable was included in the model to account for the order of the periods. Model fit was assessed through visual inspection of residual plots. Post hoc contrasts between periods are reported as mean differences and 95% confidence intervals. To account for slight deviations from normality, models were also bootstrapped with 1000 replications to estimate standard errors and the findings were consistent

with non-bootstrapped models. All analyses were conducted using Stata/IC 13.0 for Windows (StataCorp LP, College Station TX, USA).

Results

Baseline. Twenty-one participants (mean age=11.0 (SD 1.0), mean BMI=21.1 (SD 4.0), mean BMI percentile 75.0 (SD 24.0), n=11 girls) participated in the study with all participants completing the study. The complete CONSORT participant flow diagram can be seen in Figure 1. At baseline, participants had a mean MABC-2 percentile for the total score of 5.9 (SD 5.2).

The mean time spent in each intensity level can be seen in Table 1. Participants spent a higher percentage of time in MVPA during the total weekday (4.3%) compared to weekends (2.0 %, $p<.001$) and the after school period (2.7%, $p=.012$). The amount of MVPA was not significantly associated with MABC-2 scores when adjusted for wear time ($r^2=0.12$, $p=0.07$). At baseline, no participants met the physical activity recommendations of an average of 60 minutes of MVPA over the days worn (range 4 to 7), three met the recommendation during the control period, and one met the recommendation during the intervention period. At baseline, only seven participants met the recommendations on at least one day compared to eight during the no intervention period and 11 during the control periods.

Adherence. Children reported in their daily calendars of AVG usage playing an average of 140.3 (SD 62.9) minutes of AVGs per week with 19 out of 21 participants meeting the recommended minimum average of at least 80 minutes per week. The most popular games were Kinect Sports (Microsoft Game Studios, Redmond, USA) (mean 31.1 (SD 51.3) minutes per week), TV Superstars (Sony Computer Entertainment, Tokyo, Japan) (mean 14.0 SD 56.0 minutes per

week), and Dance Central (Microsoft Game Studios, Redmond, USA) (mean 12.1 (29.5) minutes per week).

Effect of intervention on objectively measured physical activity. There were no significant differences in time spent in sedentary, light, moderate or vigorous physical activity between the intervention and control periods as seen in Table 2. There were no differences during the total time or in the afterschool time specifically. Additionally, there were no significant differences in the number of breaks in sedentary behaviour or the amount of time spent in uninterrupted bouts of sedentary time greater than 30 minutes in duration.

Self-Report. Participants self-reported a non-significant increase in physical activities (not including AVGs) during the intervention (increase of 31.4 minutes 95% CI: -54.8, 117.5) which was composed of mostly an increase in walking (increase of 19.1 minutes per day 95% CI -3.4, 41.6) and ball games (increase of 30.7 minutes 95% CI -6.0, 67.4) and the increases were predominantly during weekdays. The only statistically significant change was less outdoor play on weekends during the intervention (decrease of 9.8 minutes of outside time 95% -19.5, -0.1). There were no significant differences in the use of traditional electronic games between the intervention and control periods (decrease of 16.1 minutes per week 95%CI -106.2, 74.1 during the intervention period).

Discussion

This study confirmed that children with DCD are a physically inactive and highly sedentary population in need of intervention. The current study found that these children with DCD spent less than 4 percent of their day engaged in moderate-to-vigorous physical activity. Most of the participants did not meet daily recommendations of physical activity. A similar study in Western

Australian found children without DCD to engage in 54.1 minutes of MVPA per day (Straker *et al.* 2013), compared to the 31 minutes found in the current sample.

Unfortunately, this AVG intervention did not improve the physical activity or sedentary time of the participants. There was a difference of one minute in sedentary time and 1.3 minutes in moderate physical activity between the intervention and control periods. Based on within person standard deviations of 19.6 and 6.8 for sedentary time and MVPA, a sample size of 6,033 and 432 respectively would be needed to detect these observed differences. Importantly, such small differences of one minute per day between the intervention and control would not be clinically meaningful.

The only previous intervention in children with DCD to assess physical activity participation used parent reports post-intervention and found no significant difference between the aquatic therapy and control groups (Hillier *et al.* 2010). One previous crossover within subject study of AVGs in typically developing children did not find an effect during the whole day, although AVGs did improve physical activity in the time period directly after school by 3.2 minutes per day compared to access to traditional electronic games. The current study, however, did not find any difference in the after school period. One recent trial has found that children who received access to AVGs while participating in a family-based pediatric weight management program improved moderate-to-vigorous physical activity more than those in just the program (Trost *et al.* 2014), suggesting that AVGs may be useful as an additional intervention tool in conjunction with face-to-face interventions.

While there were no differences in objective measures of physical activity, children self-reported participating in more physical activity, predominantly walking and ball sports. Unfortunately, on weekends, participants also reported a reduction in time spent outside, which may be where time was displaced for playing AVGs. This is an unintended consequence due to the many positive benefits, including physical activity, associated with outdoor play (Mainella *et al.* 2011), and thus interventions using AVGs or other indoor physical activity must take care to not displace other productive and healthy activities.

Despite finding no immediate change during the 16-week intervention, it is possible that AVG use could still have longer term effects via indirect pathways such as improved motor skill or improved attitudes towards physical activity (Straker *et al.* 2015b). Although previous analyses revealed that there were no significant improvements in motor performance (Straker *et al.* 2015a) or psychosocial outcomes (unpublished results on anxiety, general perceived competence), and physical activity enjoyment) during the intervention, participants did report improved perceptions of motor skill (Straker *et al.* 2015a) as well as improved self- and parent-reported confidence following the intervention (unpublished data). These improvements in perceptions of motor skill may lead to increased sport and physical activity participation in the longer term, but such improvements are currently speculative. Longer follow-up would determine if these changes had any longer term indirect effects on physical activity.

Strengths and Limitations. This is the first study to objectively measure physical activity during an intervention in children with DCD. The small sample size is consistent with trials in clinical populations and the within subject design increased the power. However, the small sample size and large within person variability increased the likelihood of a Type II error. It is possible that hip-worn accelerometry did not

fully capture the change in physical activity, as some activity may have been largely upper body movement during active game play. Additionally, the energy expenditure of each game provided is unknown, and children were allowed to select the games they played thus potentially resulting in lower activity levels. However, this method was meant to mimic real-world implementation of children playing at home to take advantage of the motivation and ease of access that AVGs could afford.

Conclusion

Children with DCD have a high need for interventions to increase their physical activity and decrease their sedentary behaviour. Participants at-risk for DCD in this within-subject trial did not improve objectively measured physical activity and sedentary time. The lack of impact on physical activity and sedentary time suggests that these children with DCD are on a trajectory for poorer activity which may have reverberating repercussions through adolescence and into adulthood.

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Figure Legend

Figure 1: Flow diagram outlining participant recruitment, randomisation and cross over.

Table 1: Baseline Physical Activity, mean or percent (SD)

	Total	Weekday	Weekend	Afternoon	ANOVA p-value
Wear time (min/day)	826.2 (60.7)	829.5 (62.9)	812.9 (100.1)	149.6 (0.9)	
Sedentary (min/day)	560.4 (83.8)	563.2 (83.4)	546.4 (121.1)	103.6 (13.3)	
Light (min/day)	234.8 (52.1)	231.2 (48.4)	250.2 (83.7)	42.0 (13.3)	
Moderate (min/day)	29.1 (1.9)	33.0 (2.0)	15.3 (8.7)	3.8 (3.7)	
Vigorous (min/day)	1.8 (1.7)	2.0 (14.6)	1.0 (1.3)	0.3 (0.5)	
Sedentary (%)	67.7	67.8	66.9	69.2	.881
Light (%)	28.5	28.0	31.0	28.1	.580
Moderate (%)	3.6	4.0	1.9	2.5	.001
Vigorous (%)	0.2	0.2	0.1	0.2	.391
Sedentary minutes spent in bouts of 30- 60 minutes	108.3 (49.8)	107.4 (49.7)	105.4 (70.9)	23.1 (16.5)	
Sedentary minutes spent in bouts of 60+ minutes	36.4 (31.6)	32.8 (29.0)	44.8 (83.6)	8.3 (10.7)	
Number of Breaks (per sedentary hour)	7.2 (1.7)	7.2 (1.5)	7.5 (2.9)	8.2 (3.1)	.508

Table 2: Comparison of physical activity during intervention and control periods (adjusted for wear time)

	Control (No Active Games)	Intervention (Active Games)	Difference	
	<i>Mean (SE)</i>	<i>Mean (SE)</i>	<i>Difference (95% CI)</i>	<i>p-value</i>
Total Day				
Sedentary	550.7 (11.6)	549.7 (11.6)	-1.0 (-12.1, 10.1)	.865
Light	225.1 (9.6)	227.3 (9.6)	2.2 (-8.8, 13.2)	.694
Moderate	32.5 (2.7)	31.8 (2.7)	-0.7 (-4.6, 3.3)	.733
Vigorous	3.0 (0.6)	2.4 (0.6)	-0.6 (-1.6, 0.4)	.251
Afternoons Only				
Sedentary	110.6 (3.6)	109.6 (3.6)	-2.4 (-6.2, 1.5)	.227
Light	47.6 (3.0)	49.7 (3.0)	2.1 (-1.5, 5.7)	.249
Moderate	6.5 (1.0)	5.8 (1.0)	-0.8 (-2.3, 0.7)	.284
Vigorous	0.7 (0.2)	0.4 (0.2)	-0.3 (-0.8, 0.2)	.264

Figure 1: Flow diagram outlining participant recruitment, randomisation and cross over.

