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Effectiveness of Active Video Game Usage on Body Composition, Physical Activity Level and Motor Proficiency in Children with Intellectual Disability

Abstract

Background: Interventions with active video games (AVGs) can promote physical activity (PA) and health and are compatible with a school setting. The needs of children with intellectual disability (ID) in this area have been neglected.

Methods: A two-arm trial was conducted among 203 students with ID. The intervention group was prescribed a 12-week intervention with AVG. The control group continued with usual PA.

Results: Children's BOT-2 short-form score increased in both the intervention and control groups. However, the AVG intervention had no statistically significant effect on children's body composition, PA, and motor proficiency overall, or in analyses of subgroups based on age, body weight, and comorbid autism.

Conclusion: AVG intervention had no marked effect on body composition, PA, and motor proficiency in children with ID. The reasons for the lack of effectivity of the intervention are discussed; these may provide better guidelines for future AVG intervention in children with ID.

Trial registration: ClinicalTrials.gov identifier: NCT04277130

Keywords: active video game, children, exergame, intellectual disability, motor proficiency, physical activity

1. Introduction

Active video games (AVGs) refer to video games that incorporate body movement into video game playing (Baranowski et al., 2008; . AVGs and physical activity (PA) have attracted academic interest and have been explored since 2000. In such studies, the major focus has been on PA, energy expenditure, body composition, self-efficacy, social esteem, physical fitness, cognitive learning, social skills, and sedentary behaviour in children (Barnett, Cerin & Baranowski, 2011; Getchell et al., 2012; Schneider et. al., 2012; Maddison, et al., 2012; Parisod, et al., 2014; Peng, Crouse & Lin, 2013; Rahmani & Boren, 2012; Staiano, Abraham & Calvert, 2012).

These previous studies have identified the positive effects of AVGs on children's healthy behaviour change (Staiano & Calvert, 2011), and have provided evidence supporting a training effect in which certain AVGs can produce moderate-to-vigorous PA (MVPA) in children (Foley & Maddison, 2010; Peng, Crouse & Lin, 2013). AVGs have been suggested as an attractive option to displace sedentary behaviours and increase children's PA behaviour (Lau et al., 2016). AVGs also have the following beneficial characteristics: (1) AVGs are a popular and trendy hobby in children (Mears & Hansen, 2009); (2) AVGs are a convenient and relatively low-cost, commercially available product (on systems such as PlayStation Move, Xbox Kinect, and Nintendo Wii) that provides an enjoyable experience and results in energy expenditure in children (Howcroft, et al., 2012); and (3) AVGs are an intervention that is compatible with a school setting and can result in behavioural changes related to PA and health (Lau, et al., 2015).

Children with intellectual disability (ID) could be more vulnerable to obesity than typically developing children (Maiano, 2011; Getchell et al., 2012; Wang et al., 2018). In addition to their intellectual impairment, children with ID also have delayed motor proficiency (determined by qualitatively different gross as well as fine motor development) which serves as an index of children's motor development (Hilton et al., 2014; Jung & Sainato, 2015). Since the last century, play therapy has demonstrated significant treatment effects on children's developmental needs in a school setting (Landreth, 2012). It is imperative to provide support to children with ID in order for them to have a reasonable quality of life, which may be promoted by healthy PA, motor competency, and physical fitness, despite their intellectual limitations (Martins, Carvalho & Soares, 2011). Although further research has been conducted in the past decade to understand the positive role played by AVGs in enhancing children's PA behaviour (Lu, et al., 2013; Staiano & Flynn, 2014), few studies have considered the needs of children with ID. Since children with ID show a decreased ability for social interactions, the interactive characteristics and instant feedback of AVG may improve PA, motivation, enjoyment, and perceived physical exertion in children with ID when playing with partners (Foran, 2014). With all of these characteristics, AVGs may allow the players to interact in games involving physical activity, such as tennis, football, boxing, running, and dancing.

A few studies have reported positive findings on health behaviour compliance, PA changes, and reduced repetitive behaviours through the usage of AVGs in children with special needs (e.g., autism spectrum disorders [ASD] and cerebral palsy) (Anderson-Hanley, Tureck & Schneiderman, 2010; Finkelstein, et al., 2010; Finkelstein, et al., 2013; Sandlund, Lindh Waterworth, & Häger, 2011). In the systematic review of Hickman and colleagues (2017), 20 articles were extracted on the use of AVGs to improve motor function in children with movement disorders, including cerebral palsy, developmental coordination disorder (DCD), and Down syndrome. The effects were not consistently significant as compared with conventional therapy. Additionally, the most common limitation across these studies was a small sample size. Hocking and colleagues (2019) also conducted a meta-analysis of randomized controlled trials on AVGs to improve motor function in people with developmental disabilities. The meta-analysis indicated a large effect size for AVGs to improve gross motor skills, small to medium effect sizes for improving balance, and a small, non-significant effect size for improving functional mobility. However, there has been very little research exploring whether AVGs influence body composition, PA, and motor proficiency in children with ID (Martins, Carvalho & Soares, 2011), particularly in a relatively large sample of Asian children.

Children with ID have been found to be fascinated by video games, to the point of problematic and excessive videogame play (including both sedentary video games and AVGs) (Mazurek & Engelhardt, 2013). A classic public health strategy for tackling the tricky issue between AVG treatment and problematic videogame play behaviour is to make the problem part of the solution (Pate, 2008). This strategy may be effective because children with ID are typically fascinated with electronic technology (Foran, 2014). The authors of the present study have also investigated the impacts of AVGs on PA, aerobic fitness, and exercise intensity in typically developing children (Lau, et al., 2015; Lau, Wang & Maddison, 2016) and found positive PA and fitness changes in this population as a result of using AVGs. These findings have raised the question as to whether AVGs could also be an effective intervention mode for children with ID, by helping to improve their PA, body composition and motor proficiency. We hypothesized that:

1. A prescribed AVG intervention would improve body composition and PA levels (sedentary, light, moderate, and vigorous) in children with ID.

2. The AVG intervention would enhance children's motor proficiency (fine manual control, manual coordination, body coordination, strength, balance, and speed).

3. The intervention effects would be differentiated by age, body weight, and comorbidity condition in children with ID.

This intervention study explored if the same AVG intervention approach found to be beneficial in typically developing children would be beneficial for body composition, PA, and motor proficiency in children with ID. Findings of this research may provide significant evidence that could inform health professionals and physical education (PE) teachers about the relevance of incorporation of AVGs into health promotion for children with ID.

2. Methods

2.1 Study design and participants

This was a standard two-arm parallel, single-blinded trial. Considering the feasibility of the intervention, only children with mild ID (intelligence quotient [IQ]: 55–70, American Psychiatric Association, 1994) were included in the study. The participants were recruited from special education schools in Hong Kong. IQ level was retrieved from the school records. The inclusion criteria were as follows: 1) students with ID (mild category) aged 8–18 years from special education schools, including primary and secondary schools; and 2) students without physical disability. An invitation letter to the study was sent to the Hong Chi Association, which manages 13 ID schools in Hong Kong. The Hong Chi Association is a non-profit organization in Hong Kong dedicated to serving over 7,000 students of all ages and all grades of ID. Five special education schools were willing to participate in the study. Two-hundred-and-three children (71.9% male, mean age: 12.8 [SD: 2.8 years], IQ range: 55–70) were recruited at baseline and were allocated to the intervention or control group with the assistance of the PE teachers from the participating schools. The study included 125 children in the intervention group and 78 in the control group at baseline. During the course of the study, nine children dropped out, resulting in a final sample size of 121 in the intervention group and 73 in the control group (Figure 1).

2.2 Procedures

Forms explaining the project objectives, procedures, and intervention details were provided to the participating schools, students, and their parents or guardians and informed consent was obtained for all participants. The study obtained ethics approval from the Committee on the Use of Human and Animal Subjects in Teaching and Research of Hong Kong Baptist University. All baseline and post-intervention measurements were conducted by trained undergraduate and postgraduate students. The research team members provided technical guidance and on-site coordination to set up the Xbox 360 Kinect consoles in school settings.

2.3 Intervention

Participants in the intervention group received an AVG intervention, while those in the control group received no intervention and maintained usual PA. The class size in each ID school is 15, and eight sets of Xbox 360 Kinect AVGs were provided for each class in the intervention group. The intervention group was provided with an AVG and the Xbox 360 Kinect technology. Participants were paired-up by their teachers. In this way, each participant had a classmate playing with him/her and the waiting time was minimal as the Xbox 360 Kinect allows a two-player mode. The AVG intervention consisted of two 30-min sessions per week, for a total of 12 weeks. Participants played during PE classes and/or recess. While they had no other specific routine of activities, during the intervention period, they solely played the AVG. The research team selected Xbox Sport Season Series 1 and 2 for the intervention; this comprised six different team-based and individual sport games for each season. Season 1 included boxing, track and field, 10-pin bowling, table tennis, beach volleyball, and football, while Season 2 included baseball, skiing, tennis, golf, darts, and American football. The energy expenditures of these games in the two seasons have been shown to reach moderate intensity activity (four METs) (Smallwood et al., 2012). Participants were free to choose the games they liked in the Xbox 360 Sport Season Series 1 and 2. Irrespective of the games chosen, the PA level was projected to be between moderate and vigorous intensity. School PE teachers only helped set up the AVG in the classroom, provided safety measures if needed, and offered technical assistance if a console had any problem. Teachers or researchers did not help participants when they played the AVG.

2.4 Data measurements

Participants' demographic characteristics, body composition, PA level, and motor proficiency were collected at baseline and post-intervention.

2.4.1 Demographic characteristics and body composition

Participants' sex and age were recorded. The presence of comorbid autism was identified from the school medical records. Height was measured to the nearest 0.1 cm. Weight and body fat percentage were measured using the Tanita BC-418 Body Composition Analyzer. Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared. Students with ID were then classified into the non-overweight and overweight/obesity groups by international age- and sex-specific criteria for BMI, as recommended by Cole et al. (2000).

2.4.2 Physical activity level

Objective PA level was recorded and measured using the ActiGraph GT3X+ activity monitor (Pensacola, FL). Students were asked to wear the device, positioned on the right hip, for seven consecutive days during waking hours. The accelerometer could only be removed during water-related activities (swimming, showering, and bathing) and while sleeping, and any removal was to be recorded in the PA diary given to the students. The devices were initialized at an epoch of five seconds. The wearing time was required to be at least two valid weekdays and one valid weekend day. For each valid day, a wearing time of no less than 480 minutes was required. Non-wearing periods were defined as intervals of 60 minutes or above. The cut-off points for light PA (LPA) and MVPA were higher than 100 and 2,296 counts per minute, respectively, as established by Evenson (2008).

2.4.3 Motor proficiency

The Bruininks–Oseretsky Test of Motor Proficiency™–Second Edition (BOT-2) (Bruininks & Bruininks, 2005) was used for assessment of motor proficiency. The BOT-2 is available in a complete-form, comprising 53 items, or as a short-form with 14 items selected from the complete-form. As a standardized measure of motor proficiency suitable for children and youths aged 4–21 years, both versions of the BOT-2 test are composed of four motor domains, each containing two motor subtests, i.e. 1) fine manual control: fine motor precision, fine motor integration; 2) manual coordination: manual dexterity, upper-limb coordination; 3) body coordination: bilateral coordination, balance; and 4) strength and agility: running speed and agility, strength. The BOT-2 complete-form takes approximately 60 minutes to complete, with additional time required for children with ID. Thus, we chose the BOT-2 short-form as it is more time-efficient (around 30 minutes completion time) when compared with the BOT-2 complete-form. The 14 items of the BOT-2 short-form included fine motor precision (drawing lines through paths-crooked, folding paper), fine motor integration (copying a square, copying a star), manual dexterity (transferring pennies), upper-limb coordination (dropping and catching a ball with both hands, dribbling a ball with alternating hands), bilateral coordination (jumping in place with the same sides synchronized, tapping feet and fingers with the same sides synchronized), balance (walking forward on a line, standing on one leg on a balance beam with eyes open), running speed and agility (one-legged stationary hop), strength (knee push-ups, sit-ups). The BOT-2 short-form contains a maximum total point score of 88 and sex-specific norms were used for scoring.

2.5 Statistical analysis

All statistical analyses were performed using SPSS 22.0 and a two-sided P-value was set at 0.05. The distributions of all measures were first examined by the Kolmogorov–Smirnov test. Independent *t*-tests and Mann–Whitney U tests were performed for normally distributed variables and for non-normally distributed variables, respectively, to compare the differences between the intervention and control groups at baseline and post-test. Paired *t*-tests and Wilcoxon's signed-rank tests were conducted to evaluate the differences within each group, respectively. The differences of the intervention group relative to the control group were calculated by univariate analysis in a general linear model adjusted for participants' demographic characteristics and baseline values of variables. Adjusted mean change and 95% confidence intervals (CIs) were reported as intervention effects. Considering the potential differences of intervention effects in groups with different characteristics, subgroup analyses were also performed to identify the intervention effects in different age groups (younger children aged 8–12 years vs. older children aged 13–18 years), body weight groups (non-overweight vs. overweight and obese children), and comorbidity groups (children with comorbid autism vs. those without comorbid autism).

3. Results

3.1 Characteristics of the participants at baseline

A total of 203 children participated in the study, including 125 in the intervention group and 78 in the control group. As shown in Table 1, there was no sex difference between the intervention and control groups. More than half of the participants (n = 104, 51.2%) had comorbid autism, with no significant difference across the groups: 51.4% (n

= 57) in the intervention group and 51.1% (n = 47) in the control group. However, the intervention group had more younger children (56.0%) than the control group (31.6%) (χ^2 = 11.322, p = 0.001). The overall rate of overweight and obesity was 34.0%, which was higher in the control group (48.6%) than in the intervention group (25.4%) (χ^2 = 10.485, p = 0.001). Nine children dropped out and did not participate in the post-test. Only those children (n = 194) who provided both baseline and post-test data were included in the analysis.

3.2. Overall intervention effects

AVG intervention effects on the study variables are presented in Table 2. Significant increases in BMI and body fat percentage were observed within both groups at post-test. The same trend existed for motor proficiency. Children's BOT-2 scores increased from 53.85 (standard deviation (SD): 15.25) at baseline to 57.36 (SD: 15.00) at post-test in the intervention group, while it increased from 57.86 (SD: 14.40) at baseline to 59.20 (SD: 13.86) at post-test in the control group. However, the effect of intervention after adjustment for the intervention group relative to the control group was not statistically significant for children's body composition, PA levels, or motor proficiency.

3.3 Intervention effects in different age groups

Given the significant difference in the age distribution between the intervention and control groups, a subgroup analysis was performed to identify the intervention effects in the younger age group (8–12 years) and older age group (13–18 years). These results are shown in Table 3. Among the younger children, significant increases in adiposity-related outcomes, including BMI and body fat percentage, were detected post-test within the intervention group (BMI: 17.80 kg/m^2 [SD: 2.78] at baseline vs. 18.04 kg/m^2 [SD: 2.78] at post-test, $p = 0.008$; body fat percentage: 17.75% [SD: 8.79] at baseline vs. 19.06% [SD: 9.17] at post-test, $p = 0.025$), but not within the control group. The BOT-2 score significantly increased from 50.29 (SD: 12.58) at baseline to 53.43 (SD: 15.91) at post-test in the intervention group ($p < 0.001$) and increased from 54.21 (SD: 12.58) at baseline to 58.33 (SD: 12.16) at post-test within the control group ($p < 0.001$). No significant between-group intervention effect was found for all of the outcomes among younger children (mean [95%CI] of adjusted change: -1.50 [-4.34, 1.35]). For the older children, participants in the intervention group had a decrease in MVPA and an increase in BOT-2 score after intervention, as compared to the control group. No significant difference was detected for any outcome within the control group at post-test. An intervention effect, measured by adjusted changes in the intervention group relative to the control group, was not detected for any of the outcomes.

3.4 Intervention effects in different body weight groups

Similarly, Table 4 presents the measures of all the outcomes in the subgroups categorized by non-overweight and overweight/obesity status. Among non-overweight groups, BMI in the intervention group increased at post-test (17.77 kg/m^2 [SD: 2.34] at baseline vs. 17.97 kg/m^2 [SD: 2.34] at post-test, $p = 0.004$), while MVPA decreased at post-test (56.07 min/day [SD: 22.88] at baseline vs. 45.83 min/day [SD: 18.45] at post-test, $p = 0.001$). The BOT-2 score significantly increased from 55.13 (SD: 15.61) at baseline to 59.43 (SD: 13.90) at post-test within the intervention group ($p < 0.001$), but not within the control group. However, no significant intervention effect was found across the intervention and control groups. Among children with overweight and obesity, an increase in BOT-2 score was obtained within both the intervention and control groups at post-test, while the adjusted change was not statistically significant, indicating that no marked intervention effect was detectable after the 12-week intervention with AVGs.

3.5 Intervention effects in different comorbidity groups

Given that more than half (51.2%) of the participants had comorbid autism, subgroup analysis of children with and without comorbid autism was also performed. However, we did not find intervention effects on the study variables between these two groups.

4. Discussion

Although increases in BMI, body fat percentage, and BOT-2 scores were demonstrated from baseline to post-intervention, the intervention effects with adjusted changes in the intervention group relative to the control group were not statistically significant for body composition, PA levels, or motor proficiency in children with ID. These results are in contrast to those of similar previous studies in typically developing children in Hong Kong, which demonstrated a marked post-effect of AVG intervention on aerobic fitness and PA level (Lau, Wang & Maddison, 2016). This study provides researchers with an opportunity to explore possible reasons for the effects of AVG usage by children with ID compared to those in typically developing children.

4.1 General development in AVG intervention research

It should be noted that the majority of studies that identified positive impacts of AVGs on body composition and PA levels were conducted in typically developing children (Barnett, Cerin & Baranowski, 2011; Foley & Maddison, 2010; Getchell et al., 2012; Lau et al., 2016; Maddison, et al., 2012; Parisod, et al., 2014; Peng, Crouse & Lin, 2013; Rahmani & Boren, 2012; Schneider et. al., 2012; Staiano, Abraham & Calvert, 2012). Furthermore, inconsistent findings have been reported in review papers and other studies (Burges, et al., 2016; Christison, et al., 2016; Graves, et al., 2010; Howie, et al., 2017; Straker, et al., 2015; Thivel & O'Malley, 2016; Weihrauch–Bluher, et al., 2016). For example, Burges et al. (2016) reported that school and government policies, technological failures (i.e., batteries and updates), and intervention expectations played critical roles in the effectiveness of AVG interventions. Weihrauch–Bluher et al. (2016) considered that the available studies in the literature employed markedly diverse mediums and that the program duration varied significantly across studies. These studies and review papers recommended that AVG effectiveness requires further investigation regarding its execution mechanisms in longer-term interventions.

4.2 Specific considerations in AVG intervention research among students with ID

Very few studies have investigated AVG effectiveness in changing body composition, PA, and motor proficiency in children with ID. The current study demonstrated that the AVG intervention was ineffective. Howie and colleagues (2017) investigated why AVG did not improve motor ability and PA in children with ID. They found that the game time and pattern of exposure were not responsible for the ineffective outcome. Rather, the ineffectiveness of the AVG intervention was due to the game selection, facilitators, and barriers to play. Other studies also demonstrated different reasons or factors that may help to explain the ineffectiveness of AVG interventions in children with ID (Hocking et al., 2019).

During and after the intervention, the researchers communicated with the responsible PE teachers and discussed their observations, to gain a better understanding of students' performance and feelings towards the AVG play and to gain insight into why AVG intervention did not produce positive impacts on children with ID. These observations by the teachers are described below. It should be noted that all these discussions are based upon the PE teachers' observations and experiences regarding students' performance and feelings throughout the intervention study. There may be many other confounding factors that influenced the findings of the study. Consequently, this discussion should be cautiously interpreted and should be treated as supplementary and indirect evidence. However, these possible explanations may guide future research to implement a more effective and efficient intervention for students with ID.

(1) Program dosage

Based on the majority of the AVG intervention studies with typically developing children, the minimum effective dosage regarding the exercise frequency, intensity, duration, and type were two 1-hour sessions/week for 12 weeks (Maddison, et al., 2012; Lau et al., 2016). In the present study, exercise frequency, intensity, and type were the same as in the previous studies, but the exercise time was significantly less, i.e., half the time of that used in similar previous studies. This significant reduction in training time was due to the school policy that PE lessons accounted for only two 35-minute sessions per week. In schools for typically developing children, the intervention dosage can be reached by combining two PE classes (70–90 minutes) plus after school hours. In the participating schools, for safety reasons, students must take the school bus and leave for home immediately after school. The PE class time and rigid transportation arrangement significantly reduced the dosage time and might have weakened the intervention effect. A meta-analysis conducted by Hocking and colleagues (2019) showed that variable dosages have produced inconsistent effects of AVG on motor function in children with disability. Howie and colleagues (2017) specified that 80 minutes per week was the minimum time for AVG intervention for children with disability. Hickman et al. (2017) proposed that further research regarding dosage is imperative to maximizing the potential benefits of AVG in children with movement disorders, based on their systematic review.

(2) Game selection

During the 12-week intervention, the researchers' observed that students with ID who preferred playing a few or even a single AVG game found it enjoyable. However, they seldom played multiple games or tried new games, even though these were provided. This behavioural characteristic may have reduced their adherence and increased their boredom as the intervention progressed. According to Howie et al. (2017), children with DCD showed low adherence and unwillingness to play after repetitive AVGs, even though they found the AVGs enjoyable during the initial weeks. To address this behavioural characteristic of children with ID, tailored game play should be matched and delivered to them by the researchers or teachers in future interventions to relate to the player's behaviour and the AVG narrative. This is suggested as the more similar the behavioural change information and process, the higher is the likelihood of achieving a positive behavioural change. At the same time, AVGs with dramatic tension, humour, and optimal challenges should be considered to continue to provide fun elements in the game (Thompson, 2012). Supervised play by game instructors using a variety of AVGs should be considered to ensure the relatedness and fun aspects of the AVG to the players.

(3) Game competitiveness

Howie et al. (2017) found that competitiveness could be an incentive for motivating DCD students. However, based on our observations among students with ID, competitiveness acted as a negative factor and caused emotional disturbance. During the AVG play, students with ID were significantly frustrated when they played sport games that had winners and losers. PE teachers also explained that Kinect sport games always produced feelings of losing and failure among students with ID. In contrast, they demonstrated much more pleasant emotions when playing adventure games. This response from students with ID is consistent with the finding of Staiano and colleagues (2012) that competitive AVGs induced lower intrinsic motivation than cooperative games in adolescents. They suggested that cooperative games are a better approach to engage these children in AVG play. When playing adventure games, students with ID experienced progression and advancement through scoring, and could self-pace. This self-paced content and scoring provided students with feelings of success and accomplishment. This phenomenon echoed the claim by Thompson (2012) that self-monitoring, problem-solving opportunity, and exploration are effective game features for AVG design. Thus, AVGs with win–lose games should be minimized or avoided and self-paced games should be used in future interventions for children with ID, because game competitiveness may induce lower motivation and emotional fluctuation.

(4) Game difficulty

AVGs that are physically too difficult or cognitively too complicated may be major barriers for children with ID (Howie, et al., 2017). Since AVG play time is pre-set between games and stages, students with ID felt that they needed more warm-up time to rehearse the skills needed to play more complicated games. Consequently, students found that they had insufficient time to play some games. Students with ID were also less active when playing AVGs with more demanding sport-specific skills, as these sport skills could be too challenging for them, resulting in failure and subsequent frustration. This might stop them from playing. The situation was even worse for AVGs involving rackets/clubs. Students with ID had difficulty in handling rackets/clubs in sports such as table tennis, tennis, and golf. This was supported by Thompson (2012), who reported that personal mastery is key when implementing an AVG intervention, because successful performance provided players with the concept that reaching the goal was feasible. In turn, this enhanced their self-confidence so that they would continue to play. In our intervention, the above three sports were available on Kinect Sports Seasons I & II. These AVG racket sports might deter students' from playing. Future AVG interventions should avoid using racket sports. Furthermore, different games had different cognitive requirements for responses. According to the observations relayed by their teachers, although all participants were students with mild ID (IQ: 55–70), some of them still found it difficult to follow the AVG instructions. For example, track and field games required use of their imagination and running in the same spot without moving their body forward. In this case, students with ID felt very confused and could not execute the expected movements or even stopped playing this game. However, they showed greater preference towards adventure games because they liked the real-world background, such as trees, forests, waterfalls, etc., and because less sport-specific skills were required. Therefore, simple sport skills and realistic backgrounds should be selected in future interventions.

(5) Efficiency of the AVG setting

The schools spent significant time to set up training, change the games, and explain the AVG instructions during the 30-minute intervention. As Howie et al. (2017) commented, the inefficiency of the AVG setting highly reduced the impact of AVGs on students with ID.

(6) Transfer of motor proficiency

According to the studies of Hocking et al. (2019) and Howie et al. (2017), no conclusion could be drawn regarding the AVG impact on motor ability in children with ID. Furthermore, whether the skills learnt in the AVG (i.e., virtual world) could be transferred to the real world remains unconfirmed (Thompson, 2012). In the present study, this was an even more complicated issue because the participants had ID and their motor proficiency may be delayed. Whether or not the AVG content matched their ability to improve needs to be addressed in future research. The Challenge Point Framework (Guadagnoli and Lee, 2004), was used to assess the issue of motor ability. This framework states that motor tasks present different challenges to individuals with different abilities and that the learning effect depends upon the current motor skill level of the participant, task difficulty, and the task environment. The key to motor ability improvement is to establish the optimal challenge point that can maximize learning and minimize barriers. Therefore, this framework suggests that researchers should consider the adjustment of participants' current motor skill level, task difficulty, and the task environment. Likewise, Wulf and Lewthwaite (2016) suggested that motivational and attentional factors can better bridge the expected goals into actions. The explanation for their theory lies in three major elements: expectancy effect, learner autonomy, and external focus for the establishment of functional connections. They suggested that this mechanism helps the participants advance their motor learning ability through their cognitive and motor systems. Taken together, to establish the optimal challenge point and bridge the expectancy effect, learner autonomy and external focus of the participants in terms of motor ability improvement should be considered in future intervention studies in children with ID.

(7) Socially interactive AVGs

Social interaction and peer support have been reported to occur during AVG participation; previous literature has demonstrated a positive impact thereof on motivation to participate and enjoyment of AVG (Marker & Staiano, 2014). However, during the intervention, students with ID demonstrated difficulty with playing when the AVG requested them to interact with other students, in either cooperative or competitive play. It is understandable that students with ID, especially those with autistic symptoms, would have problems with interacting and cooperating with others. In the present study, more than 50% of the participants had ID with autistic symptoms. These social interactive AVGs might be a barrier for them and may lower their motivation to play. Therefore, individual AVGs may be more appropriate for this population. Feltz et al., (2012) and Thompson (2012) suggested an alternative, in that an avatar may be an ideal approach for motivating participation and sustainability of AVG play. An avatar can avoid interaction or communication problems in children with ID and can achieve the effect of modelling, cooperation, and interactivity. Since players may identify with the avatar, it may have a reinforcing effect on them.

(8) Role of the PE teacher and teacher/student ratio

At the beginning of the intervention, students with ID, particularly those with autistic symptoms, demanded that their PE teachers be with them and help start the AVGs. This process was not only related to the technical issues (i.e., instructions and knowledge) regarding AVG play, but was also linked to trust, security, and social support, and provided a positive social experience to overcome the barriers to play (Howie et al., 2017). In the present study, it had not been planned that the PE teacher would act as a facilitator in the intervention. However, based upon the participants' response, PE teachers' facilitation should be included in the intervention as this may improve students' adoption and continuation of AVG play. However, the current teacher/student ratio in schools for children with ID in Hong Kong is 2:15. This ratio cannot produce a satisfactory outcome during the 30-minute sessions. If the teacher/student ratio can be enhanced, PE teachers can act as a facilitator in order to balance game selection better, help solve technical problems, and increase social support and security during the entire intervention process. Individual assistance from teachers to students with ID is a significant factor for ensuring the quality of AVG delivery and producing effective intervention outcomes.

4.3 Limitations of the study

This study had some limitations. In the current study, the participant allocation resulted in an unequal distribution of age and body weight status in the intervention and control groups at baseline. These results remained even though subgroup analyses (i.e., younger vs. older groups; non-overweight vs. overweight/obesity groups) were performed and baseline values were adjusted in the statistical models. Such imbalanced allocation might impact the findings of AVG effects. Further studies with more balanced distribution are required.

5. Conclusion

Although AVG interventions have been reported to be successful in enhancing PA among typically developing children (Lau et al., 2016), the present study did not find this enhancement effect among children with ID. Reasons for the lack of effect of AVG intervention in terms of changing body composition, PA, and motor proficiency in students with ID were discussed. These findings may allow improvements in future AVG interventions for children with ID. To maximize the AVG technology for this special needs population, the quality of the AVGs and the specific behavioural/emotional characteristics of the children with ID should be considered and matched, as these factors are significantly different from those of their typically developing counterparts. This may help to increase children with ID’s motivation for and minimize their barriers to playing AVGs, thereby enhancing PA, motor proficiency, and health among children with ID.

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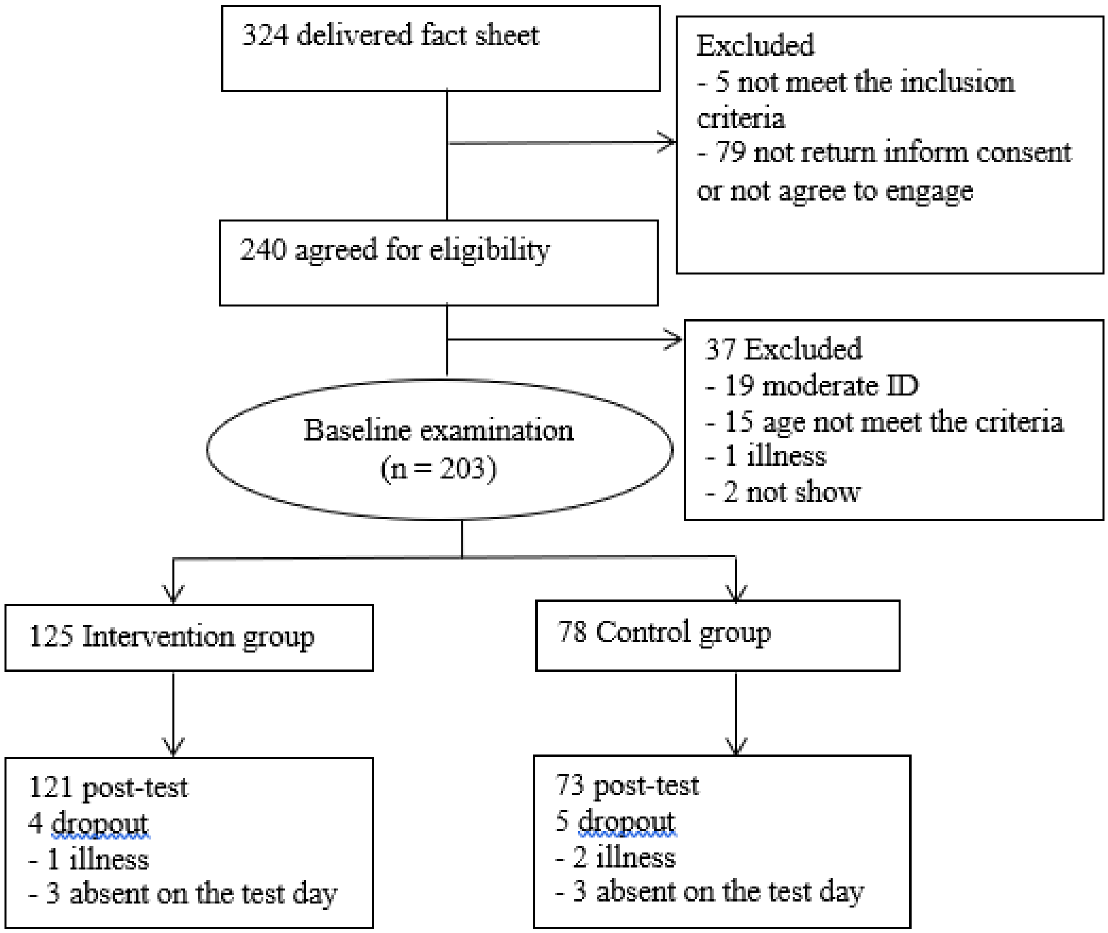

Figure 1. Participants flow diagram

Table 1

Participants' sex and age distributions at baseline

	Overall (n = 203)	Intervention (n = 125)	Control (n = 78)	Statistics (χ^2)	*p* value
Sex, n (%)					
Males	146 (71.9)	92 (73.6)	54 (69.2)	0.454	0.524
Female	57 (28.1)	33 (26.4)	24 (30.8)		
Age (years), n (%)					
8-12	94 (49.8)	70 (56.0)	24 (31.6)	11.322	0.001
13-18	107 (50.2)	55 (44.0)	52 (68.4)		
Body weight status, n (%)					
Non-overweight	124 (66.0)	88 (74.6)	36 (51.4)	10.485	0.001
Overweight/obesity	64 (34.0)	30 (25.4)	34 (48.6)		
Co-morbidity with autism					
No	99 (48.8)	54 (48.6)	45 (48.9)	0.002	0.999
Yes	104 (51.2)	57 (51.4)	47 (51.1)		

Table 2

AVG intervention effect on the study variables

	Intervention group (n=125) Mean (SD)	Control group (n=78) Mean (SD)	P[a]	Adjusted change[c] Mean (95%CI)
Body composition				
Body mass index (BMI, kg/m^2)				
Baseline	19.17(3.53)	22.24 (4.83)	<0.001	
Post-test	19.19 (3.36)	22.14 (4.71)	<0.001	-0.17 (-0.47, 0.14)
p[b]	<0.001	<0.001		
Body fat percentage (%)				
Baseline	18.57 (8.76)	24.07 (10.88)	0.106	
Post-test	18.49 (8.73)	23.03 (10.26)	0.060	0.04 (-1.23, 1.30)
p[b]	<0.001	<0.001		
Physical activity levels				
Sedentary time (min/day)				
Baseline	561.10 (88.79)	529.89 (81.22)	0.856	
Post-test	558.47 (61.71)	552.57 (91.33)	0.025	-12.45 (-47.56, 22.67)
p[b]	<0.001	0.045		
Light physical activity (min/day)				
Baseline	168.08 (35.21)	176.26 (52.09)	0.008	
Post-test	167.64 (43.87)	172.37 (62.30)	0.016	-2.12 (-16.98, 12.74)
p[b]	<0.001	<0.001		
Moderate-to-vigorous physical activity (min/day)				
Baseline	56.64 (21.84)	51.29 (25.17)	0.692	
Post-test	46.97 (18.73)	51.73 (23.91)	0.373	-3.83 (-9.77, 2.10)
p[b]	<0.001	<0.001		
Motor proficiency				
BOT-2 score				
Baseline	53.85 (15.25)	57.86 (14.40)	0.138	
Post-test	57.36 (15.00)	59.20 (13.86)	0.270	0.59 (-1.28, 2.46)
p[b]	<0.001	0.003		

Notes:
[a] p-value for comparison between groups by Mann-Whitney U test for BOT-2 score, and by independent t-test for other variables.
[b] p-value for comparison within groups at post-test compared with baseline by Wilcoxon matched-pair signed rank test for BOT-2 score, and by paired t-test for other variables.

[c] Adjusted change mean and 95% confidence interval (CI) are the differences of the intervention group relative to control group by univariate analysis in general linear model adjusted for sex, BMI, comorbidity with autism, and baseline assessment of the variable.
[*] $p < 0.05$
CI, confidence interval; SD, standard deviation.

Table 3

AVG intervention effect on the study variables in different age groups

	Younger age group (8-12yrs)				Older age group (13-18yrs)			
	Intervention group (n=68)	Control group (n=23)	P[a]	Adjusted change[c]	Intervention group (n=53)	Control group (n=49)P[a]	P[a]	Adjusted change[c]
	Mean (SD)	Mean (SD)		Mean (95%CI)	Mean (SD)	Mean (SD)		Mean (95%CI)
Body composition								
Body mass index (BMI, kg/m^2)								
Baseline	17.80 (2.78)	20.06 (4.50)	0.007		20.84 (3.65)	23.23 (4.68)	0.005	
Post-test	18.04 (2.78)	20.54 (4.77)	0.003	-0.06 (-0.57, 0.45)	20.63 (3.49)	22.88 (4.55)	0.006	-0.23 (-0.61, 0.16)
p[b]	0.008	0.190			0.965	0.787		
Body fat percentage (%)								
Baseline	17.75 (8.79)	23.55 (11.35)	0.015		19.60 (8.69)	24.31 (10.78)	0.017	
Post-test	19.06 (9.17)	23.87 (10.64)	0.041	0.88 (-1.46, 3.23)	17.77 (8.18)	22.64 (10.17)	0.009	-0.52 (-1.85, 0.82)
p[b]	0.025	0.859			0.061	0.120		
Physical activity levels								
Sedentary time (min/day)								
Baseline	534.66 (87.19)	517.14 (53.79)	0.538		589.42 (82.88)	541.94 (85.92)	0.046	
Post-test	555.94 (55.00)	487.53 (73.79)	0.016	43.00 (-2.77, 88.77)	560.88 (68.78)	582.92 (84.13)	0.394	-47.69 (-97.25, 1.87)
p[b]	0.731	0.416			0.521	0.124		
Light physical activity (min/day)								
Baseline	172.30 (20.09)	199.61 (44.89)	0.030		163.56 (40.06)	163.67 (51.72)	0.994	
Post-test	179.47 (37.00)	229.97 (50.98)	0.009	-16.22 (-41.88, 9.43)	156.37 (47.70)	163.66 (51.72)	0.505	4.36 (-17.58, 26.30)
p[b]	0.611	0.150			0.128	0.125		
Moderate-to-vigorous physical activity (min/day)								

Baseline	55.12 (20.58)	46.73 (16.02)	0.230		52.28 (23.38)	53.60 (28.74)	0.516	
Post-test	43.57 (16.62)	42.57 (19.72)	0.250	-7.10 (-15.95, 1.74)	50.22 (20.40)	51.33 (26.28)	0.887	-1.90 (-10.68, 6.88)
p[b]	0.053	0.353			0.003	0.128		
Motor proficiency								
BOT-2 score								
Baseline	50.29 (12.58)	54.21 (12.58)	0.276		58.31 (13.60)	58.88 (14.84)	0.566	
Post-test	53.43 (15.91)	58.33 (12.16)	0.189	-1.50 (-4.34, 1.35)	62.22 (12.28)	61.02 (14.05)	0.921	1.76 (-4.22, 0.70)
p[b]	<0.001	<0.001			<0.001	0.180		

Notes:

[a] p-value for comparison between groups by Mann-Whitney U test for BOT-2 score, and by independent t-test for other variables.

[b] p-value for comparison within groups at post-test compared with baseline by Wilcoxon matched-pair signed rank test for BOT-2 score, and by paired t-test for other variables.

[c] Adjusted change mean and 95% confidence interval (CI) are the differences of the intervention group relative to control group by univariate analysis in general linear model adjusted for sex, BMI, comorbidity with autism, and baseline assessment of the variable.

[*] $p < 0.05$

CI, confidence interval; SD, standard deviation.

Table 4

AVG intervention effect on the study variables in different body weight groups

	Non-overweight group				Overweight and obesity group			
	Intervention group (n=88)	Control group (n=36)	P[a]	Adjusted change[c]	Intervention group (n=30)	Control group (n=30)P[a]	P[a]	Adjusted change[c]
	Mean (SD)	Mean (SD)		Mean (95%CI)				
Body composition								
Body mass index (BMI, kg/m^2)								
Baseline	17.77 (2.34)	18.66 (2.61)	0.067		23.27 (3.24)	26.03 (3.56)	0.002	
Post-test	17.97 (2.34)	18.95 (2.65)	0.046	0.05 (-0.30, 0.39)	23.28 (2.96)	26.05 (3.35)	0.001	-0.55 (-1.17, 0.06)
p[b]	**0.004**	0.349			0.774	0.582		
Body fat percentage (%)								
Baseline	15.06 (6.79)	16.86 (7.53)	0.197		28.77 (5.05)	31.71 (8.41)	0.101	
Post-test	15.21 (6.15)	17.09 (7.69)	0.164	-0.43 (-2.04, 1.17)	29.21 (6.86)	30.33 (8.03)	0.565	1.13 (-0.83, 3.10)
p[b]	0.403	0.744			0.510	0.056		
Physical activity levels								
Sedentary time (min/day)								
Baseline	573.36 (82.51)	551.79 (83.48)	0.366		541.19 (92.16)	515.13 (72.89)	0.464	
Post-test	559.92 (61.25)	163.14 (49.31)	0.694	-19.03 (-56.31, 18.26)	551.61 (69.85)	561.07 (93.93)	0.837	-5.08 (-86.69,46.54)
p[b]	0.610	0.358			0.886	0.517		
Light physical activity (min/day)								
Baseline	168.24 (36.54)	163.14 (49.31)	0.651		167.61 (34.91)	193.54 (58.42)	0.164	
Post-test	170.60 (46.03)	154.86 (56.20)	0.338	6.56 (-12.42, 25.54)	155.34 (37.80)	204.92 (65.54)	0.071	-19.73 (-65.78, 26.32)

p[b]	0.760	0.300			0.345	0.532		
Moderate-to-vigorous physical activity (min/day)								
Baseline	56.07 (22.88)	50.47 (25.04)	0.387		55.50 (19.48)	44.69 (17.31)	0.145	
Post-test	45.83 (18.45)	47.00 (23.33)	0.860	-4.82 (-12.73, 3.10)	50.29 (21.33)	45.13 (23.67)	0.664	-5.96 (-18.56, 6.64)
p[b]	0.001	0.671			0.425	0.953		
Motor proficiency								
BOT-2 score								
Baseline	55.13 (15.61)	57.83 (15.69)	0.142		52.80 (13.27)	58.13 (11.26)	0.345	
Post-test	59.43 (13.90)	61.34 (13.20)	0.319	0.66 (-1.81, 3.12)	55.03 (12.94)	59.09 (12.03)	0.445	1.19 (-2.00, 4.36)
p[b]	<0.001	0.208			<0.001	<0.001		

Notes:

[a] p-value for comparison between groups by Mann-Whitney U test for BOT-2 score, and by independent t-test for other variables.

[b] p-value for comparison within groups at post-test compared with baseline by Wilcoxon matched-pair signed rank test for BOT-2 score, and by paired t-test for other variables.

[c] Adjusted change mean and 95% confidence interval (CI) are the differences of the intervention group relative to control group by univariate analysis in general linear model adjusted for sex, age, comorbidity with autism, and baseline assessment of the variable.

[*] $p < 0.05$

CI, confidence interval; SD, standard deviation.