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Original Article

Are Active Video Games Effective at Eliciting Moderate-Intensity Physical Activity in Children, and Do They Enjoy Playing Them?

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ABSTRACT

Background: Despite current physical activity (PA) guidelines, children spend an average of 1-3 hours/day playing video games. Some video games offer physically active components as part of gameplay. We sought to determine if these active video games (AVGs) can elicit at least moderate PA in children, identify game elements important for PA, and determine if they are fun to play.

Methods: Twenty children aged 8 to 16 years underwent cardiopulmonary exercise testing to determine their heart rate (HR) at ventilatory threshold. Participants played 2 different AVGs, and the gaming time that each participant's HR was above the HR thresholds for moderate and vigorous PA was determined. Gameplay elements that supported or inhibited active gameplay were also identified. Participants also completed questionnaires on physical activity, game engagement, and game experience.

Results: The *Dance Central Spotlight* and *Kung-Fu for Kinect* AVGs produced at least moderate PA, for a mean of 54.3% ± 29.5% and

RÉSUMÉ

Contexte : Malgré les lignes directrices actuelles sur l'activité physique, les enfants passent en moyenne entre une et trois heures par jour à jouer à des jeux vidéo. Comme la jouabilité de certains jeux vidéo comporte des activités physiques, nous avons cherché à déterminer si les jeux vidéo dynamiques (JVD) pouvaient permettre aux enfants d'atteindre un degré d'activité physique au moins modéré, à cerner les éléments de jeu qui sont importants pour l'activité physique et à déterminer si ces jeux étaient amusants.

Méthodologie : Nous avons soumis 20 enfants de 8 à 16 ans à des épreuves d'effort cardiopulmonaire pour déterminer leur fréquence cardiaque (FC) au seuil ventilatoire. Les participants ont joué à deux JVD différents et nous avons déterminé la durée pendant laquelle la FC de chaque participant était supérieure aux seuils de FC correspondant à une activité physique modérée et intense. Nous avons aussi cerné les éléments de la jouabilité qui favorisaient ou empêchaient la jouabilité dynamique. Les participants ont en outre rempli des

Children spend ~7 hours/day in sedentary behaviors, including being in front of a video screen playing games, consuming media, and socializing.[1] This amount of time far exceeds the recommended maximum of 2 hours of screen time per day,[2] while also impacting valuable sleep time[3] and healthy dietary behaviors.[4] The current physical activity (PA) recommendations for children aged between 5 and 17 years is at least 60 minutes of moderate-to-vigorous—intensity PA (MVPA) per day.[5] Unfortunately, most children are not achieving this goal,[6,7] and the high level of sedentary behavior and lack of proper sleep have serious consequences for both their physical and mental health.[4,8]

Playing video games is extremely popular among children, and most of these games are sedentary. Some video games require the players to be active and move their body in order to play through motion-sensing technology.[9] Randomized controlled trials have shown that active video games (AVGs) can improve PA levels and weight loss in children.[10-13]

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Ethics Statement: The study was approved by the Western University, London, Ontario, Canada Research Ethics Board (REB#108666).

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87.8% ± 21.8% of gameplay time, respectively. Full-body movements, player autonomy, and self-efficacy were observed to be important elements of good AVG design. Although participants enjoyed these AVGs, they still preferred their favorite games (game engagement score of 1.82 ± 0.67 vs 0.95 ± 0.70 [*Dance Central Spotlight*] and 1.39 ± 0.37 [*Kung Fu for Kinect*]).

Conclusions: AVGs can provide at least moderate PA and are enjoyable to play, but most popular video games do not incorporate active components. The implementation of government policies and a rating system concerning PA in video games may help address the widespread sedentary lifestyle of children.

questionnaires sur l'activité physique, l'intérêt des jeux et l'expérience de jeu.

Résultats : Deux JVD, *Dance Central Spotlight* et *Kung-Fu for Kinect*, ont produit un degré d'activité physique au moins modéré pendant respectivement 54,3 % ± 29,5 % et 87,8 % ± 21,8 % de la durée de jouabilité. Nous avons constaté que les mouvements du corps entier, l'autonomie des joueurs et l'auto-efficacité étaient des éléments importants de la bonne conception d'un JVD. Les participants ont aimé ces JVD, mais ils préféraient toujours leurs jeux favoris (score d'intérêt à l'égard du jeu de 1,82 ± 0,67 vs 0,95 ± 0,70 [*Dance Central Spotlight*] et 1,39 ± 0,37 [*Kung Fu for Kinect*]).

Conclusions : Les JVD semblent produire un degré d'activité physique au moins modéré et sont amusants, mais la plupart des jeux vidéo populaires ne font pas faire d'activité physique. La mise en œuvre de politiques gouvernementales et l'adoption d'un système de cotation concernant l'activité physique associée aux jeux vidéo pourraient permettre de s'attaquer au problème répandu que représente la sédentarité chez les enfants.

Unfortunately, the level of PA elicited by AVGs has also been shown to be inconsistent, and player engagement not long-lasting.[14-16] The reasons for these effects are that the intensity of player activity required varies between AVGs[17] and children often lose interest in playing games due to the games no longer being fun.[18]

The purpose of this study was to determine if the selected AVGs can elicit MVPA in children, to identify which game design aspects are important to attain MVPA, and to compare the levels of engagement and enjoyment of these AVGs to those for the participants' current favorite game.

Methods

Participant recruitment and enrollment

Healthy children aged between 8 and 18 years, who had no history of heart disease and were able to perform PA without limitations were recruited through posters posted in the hospital and through word of mouth. The study was conducted in the Paediatric Cardiopulmonary Research Laboratory at the Children's Hospital, London, Canada. Informed written consent was obtained from all participants and/or their legal guardian. Participants attended 3 sessions on different days, one for cardiopulmonary exercise stress testing (CPET), and 2 for playing video games.

CPET

The age, gender, height, and weight of each participant was recorded on the first visit. Subjects underwent CPET with oxygen consumption (VO_2) measurement, using the V_{max} Encore Pulmonary Function Testing system (Carefusion, Yorba Linda, CA), and an Ergoselect 150 Kind stationary cycle ergometer (Ergoline GmbH, Bitz, Germany). A ramp protocol was used that was tailored to each participant aiming to achieve volitional fatigue by 10-12 minutes. The ramp protocol is based on the estimated maximal work in watts to reach volitional fatigue for each subject ($(2.76 \times height_{cm}) - 276$). This estimate is used to determine the incremental work rate required to reach this endpoint over the course of the 10-minute exercise phase. The work rate is gradually and evenly increased over the course of the 10-minute exercise phase. The predicted peak VO_2 (VO_{2max}) was determined using the equations from Jones and Campbell (1982) (Male: VO_2 (L/min) $= 4.2 - (0.032 \times age)$, and Female: VO_2 (L/min) $= 2.6 - (0.014 \times age)$).[19] Peak VO_2 was measured, and the heart rate (HR) at ventilatory threshold (HR@VT) was determined for each participant. VT was determined using both the V-slope and dual criteria methods.[20,21]

Active gaming sessions

Microsoft Kinect for the XBox One (Microsoft, Redmond, WA), a body movement—sensing device, was used. Approximately 80 commercially available games that required a Kinect to play were assessed to determine the (i) PA required, (ii) initial learning curve, and (iii) appropriateness to the participants' age range. Six games were then pilot tested by members of the research team to further assess the players' PA requirements and enjoyment level. Based on the amount of body movement required for gameplay (eg, both arm and leg movement required), the level of learning difficulty (eg, easy to learn and perform movements), and overall appeal (eg, enjoyable for all ages and genders), *Dance Central Spotlight* (DC; Harmonix Music Systems, Boston, MA) and *Kung-Fu for Kinect* (KF; Virtual Air Game Company, Helsinki, Finland) were selected as the most appropriate for the study. Participants played each game for up to 40 minutes. Random-block assignment was used to determine the order in which participants played the games.

HR monitoring during gameplay

A Polar H10 HR monitor (Polar, Kempele, Finland) was used to record the beat-to-beat RR intervals, and the HR was then calculated from the RR intervals using the Heart Rate Variability Logger software (A.S.M.A. B.V., Amsterdam, Netherlands),[22] available on the Apple App Store. RR intervals were recorded roughly every 0.5 seconds. To match the HR intervals to the various gameplay time points (eg, difficulty levels, non-gameplay time between levels), each participant was observed in real time, and the time was recorded.

Determining gameplay PA intensity

The proportion of time a participant was engaged in at least moderate-intensity PA was determined based on the participant's HR at 2 levelsHR@VT and $\geq$ 50% of their estimated maximal heart rate (HR_{max} = 220 − age), which corresponds to $\geq$ 3.0 metabolic equivalents.[23] Similarly, vigorous PA was defined as a HR $\geq$ 70% of HR_{max} and corresponds to $\geq$ 6.0 metabolic equivalents.[23] The proportion of recorded HR values $\geq$ the predetermined HR thresholds was determined. Only the time points at which the participants were engaged in active gameplay were considered.

PA and gaming questionnaires

Participants completed the Demographics Questionnaire, the PA Questionnaire for Children or the one for Adolescents,[24] the Game Engagement Questionnaire,[25] and the Game Experience Questionnaire v13.0[26] (Supplemental Appendix S1).

The Demographics Questionnaire provided information on game-playing habits, gamer identity, and gaming preferences. The PA Questionnaire for Children and the one for adolescents were used to gather general physical activity levels of participants.[24]

Questionnaires were also used to measure participants' enjoyment of their self-declared favorite game and the 2 AVGs tested. The Game Engagement Questionnaire is a psychometrically strong measure of the depth of engagement individuals have while playing a video game, and the Game Experience Questionnaire is a 7-scale measure of various facets of an individual's experience.[25,26] A repeated-measures analysis of variance with Bonferroni pairwise testing was used to compare the mean questionnaire scores (IBM SPSS Statistics V25, IBM, Armonk, NY).

Results

Participants

Twenty (n = 20) healthy participants between the ages of 8 and 16 years were recruited. Demographic and physiological details are summarized in Table 1. Three participants dropped out of the study and only completed 1 of the 2 gaming sessions—2 did not play KF, and 1 did not play DC, as indicated.

CPET

The results from the CPET are presented in Table 2. The participants averaged 76.7% ± 17.0% of predicted VO_{2max}, and 40% achieved $\geq$ 85% of predicted VO_{2max}. The HR at peak VO_2 was 186 ± 17 beats per minute, which was significantly lower relative to the HR_{max} of 208 ± 2 beats per minute ($P \leq 0.001$). Participants averaged 89.5% ± 8.3% of HR_{max} on the exercise test. All but 3 participants scored above 80% of predicted peak HR (peak HR/HR_{max}).

Gaming demographics and PA questionnaires

Participants identified themselves as being in one of 6 categoreis from "not a gamer" to "hardcore gamer," and only one had never played an AVG (Supplemental Table S1A). The majority (60%) preferred playing video games over outside PA, and 25% preferred playing video games alone over any form of social play (Supplemental Table S1B). The majority of participants reported playing games for at least 2-4 hours daily, and a session lasted ~2 hours (Supplemental Table S1C). Four participants (20%) reported only single-player games as their favorites (Supplemental Table S1D).

The PA Questionnaire was completed by 14 participants, with a score of 2.49 ± 0.76 (range: 1.11, 3.94). Five participants (36%) were attaining a reasonable level[27] of MVPA/day based on a cutoff score of 2.75.

Total gameplay time

The gameplay time for DC was 26.3 ± 7.2 minutes, ~45% of which was on the hard levels (Supplemental Table S2). Five participants ended the gaming session early, 2 of whom did not play the hard levels. Participants stopped early because of "exhaustion" (60.0%) or because they "lost interest" (40.0%). Four participants played for 10 to 20 minutes beyond the scheduled time.

Participants played KF for 26.8 ± 10.2 minutes, ~77% of which was on the hard levels (Supplemental Table S2). Seven participants ended the gaming session early. All participants completed the easy levels and some of the hard levels. Participants stopped early, citing as the reason either "cannot progress" (57.1%), "exhaustion" (28.6%), or "lost interest" (14.3%). Five participants played for 10 to 25 minutes beyond the scheduled time.

MVPA based on HR@VT

The HR PA intensity thresholds are listed in Table 3. The proportion and amount of gameplay time at each

Table 1. Anthropomorphic measurements of N = 20 study participants

	All (N = 20)		Females (n = 8)			Males (n = 12)		
Anthropomorphic measures	Mean	SD	Mean	SD	Range	Mean	SD	Range
Age (y)	11.8	2.5	12.1	2.2	8,14	11.5	2.8	8, 16
Weight (kg)	46.4	11.8	48.5	8.1	31.3, 56.8	45.1	13.9	25.4, 60.0
Height (cm)	154	14	156	11	133, 164	152	16	128, 173
BMI z-score	0.23	0.98	0.46	0.54	−0.46, 1.10	0.07	1.18	−1.79, 2.44
BMI percentile	57	28	66	19	32, 86	51	32	4, 99
Resting HR (bpm)	78	10	80	8	70, 93	76	11	63, 97

BMI, body mass index; bpm, beats per minute; HR, heart rate; SD, standard deviation.

Table 2. Exercise stress test outcomes of N = 20 study participants

Exercise stress test outcome	All (N = 20) Mean	All SD	Females (n = 8) Mean	Females SD	Females Range	Males (n = 12) Mean	Males SD	Males Range
Peak VO_2% of predicted (%)	76.7	17.0	73.3	19.1	51.5, 99.8	78.9	15.9	51.6, 103.9
RER	1.13	0.10	1.14	0.10	0.98, 1.25	1.12	0.10	0.97, 1.32
Peak HR (bpm)	186	17	188	17	160, 206	185	18	153, 214
HR_{max} (bpm)	208	3	208	2	206, 212	209	3	204, 212
Peak HR / HR_{max} (%)	89.5	8.3	90.7	8.3	75.8, 100.0	88.7	8.5	72.5, 101.4

bpm, beats per minute; HR, heart rate; HR_{max}, maximum HR = 220 − age; RER, respiratory exchange ratio; VO_2, oxygen uptake.

HR threshold are listed in Table 4 and Supplemental Table S2, respectively. While playing DC, the participants' HR was ≥ HR@VT for 54.3% ± 29.5% of gaming time. One participant's HR never reached HR@VT. For the easy levels, participants reached HR@VT for 42.6% ± 31.0% of gaming time. Four participants never reached HR@VT, and 2 reached HR@VT for short periods of time (8.6% and 11.3%). For the hard levels, participants reached HR@VT for 74.0% ± 25.4% of gaming time. For KF, participants reached HR@VT for 87.8% ± 21.8% of gaming time. For the easy levels, participants reached HR@VT for 73.6% ± 26.6% of gaming time. One participant's HR never reached HR@VT. For the hard levels, participants reached HR@VT for 91.5% ± 22.0% of gaming time.

MVPA based on HR_{max}

For DC, participants' HRs were ≥ 50% HR_{max} for 87.6% ± 16.2% of gaming time (Table 4; Supplemental Table S2). All participants experienced moderate PA (MPA). The participants' HRs were ≥ 70% HR_{max} for 22.8% ± 28.5% of gaming time. Five participants did not experience vigorous PA (VPA), and 5 participants experienced it for < 3 minutes. For KF, participants' HRs were ≥ 50% of HR_{max} for 97.3% ± 4.4% of gaming time (Table 4; Supplemental Table S2) and ≥ 70% HR_{max} for 63.1% ± 32.3% of gaming time. All participants experienced some MPA and VPA.

Enjoyment of tested AVGs

The mean engagement difference was statistically significant ($P \leq 0.05$) for the participants' favorite game (1.82 ± 0.67) vs DC (0.95 ± 0.70), but not vs KF (1.39 ± 0.37; Table 5). The positive subscales of gaming experience for the participants' favorite game, with the exception of the challenge subscale, were significantly higher ($P \leq 0.05$) in their favorite game relative to DC, but not to KF (Table 5). There were no significant differences between the games for the negative subscales.

Discussion

Children are not getting enough PA and spend too much time playing video games. This study demonstrated that select AVGs successfully elicited MVPA in children and determined that player engagement was important for attaining and maintaining MVPA. Several game design elements were identified that resulted in increased MVPA, leg movements, and freedom to choose movements in particular, as well as elements that negated MVPA, such as the ability to circumvent game mechanics. However, when players found gameplay too difficult, this became a deterrent and resulted in a loss of player engagement and reduced levels of PA.

PA intensity

According to the American Heart Association, 50% of your maximal HR is a target HR for moderate PA.[23] Based on this, the participants were able to attain at least MPA for 88% and 97% of gameplay time for DC and KF, respectively. However, based on the HR@VT, the overall active gaming time for DC was reduced, whereas it remained strong for KF. Although the PA intensity threshold based on HR_{max} is a useful method for self-determined PA intensity, the HR@VT is more relevant for gauging the competence of a particular mode of PA. The HR@VT is not an arbitrary threshold, such as "50% of HR_{max}," and it is empirically determined for each individual at a specific point in time. Regardless, both AVGs were capable of providing at least MPA in children, especially at the higher difficulty levels.

Capability of DC and KF to provide MVPA

DC was less successful than KF at providing MVPA for several reasons. First, it was possible to complete a move with minimal effort. The tracking of certain moves was lenient, and this could be exploited to reduce the effort required to succeed. However, circumventing intended gameplay mechanics to "cheat" is not unexpected.[28] In contrast, cheating may be

Table 3. Physical activity heart rate (HR) thresholds (N = 20)

HR thresholds	HR (bpm) Mean	SD	Range	Median	IQR
HR@VT (bpm)	126	11	107, 147	125	120, 134
VT/HR_{max} (%)	60	5	51, 71	60	57, 64
VT/HR_{peak} (%)	68	6	58, 77	67	64, 73
50% HR_{max} (bpm; moderate)	104	1	102, 106	104	103, 106
70% HR_{max} (bpm; vigorous)	146	2	143, 148	146	144, 148

bpm, beats per minute; HR_{max}, maximum HR; HR@VT, HR at ventilatory threshold; IQR, interquartile range; SD, standard deviation; VT, ventilatory threshold.

Table 4. Proportion of gameplay time heart rate (HR) is at or above the HR thresholds for physical activity intensity

		% Gameplay time					
		DC			KF		
HR threshold	Levels	Mean	SD	Range	Mean	SD	Range
≥ HR@VT	All	54.3	29.5	0.0, 94.6	87.8	21.8	5.1, 100
≥ 50% HR_{max}		87.6	16.2	55.8, 100	97.3	4.4	83.4, 100
50% < 70% HR_{max}		64.9	24.3	15.5, 98.9	34.2	32.5	3.4, 95.0
≥ 70% HR_{max}		22.8	28.5	0.0, 84.5	63.1	32.3	1.1, 96.6
≥ HR@VT	Easy	42.6	31	0.0, 92.0	73.6	26.6	0.0, 100
≥ 50% HR_{max}		81.1	25	27.0, 100	94.4	7.6	76.6, 100
50% < 70% HR_{max}		66.2	26.4	27.0, 98.9	47	29.3	5.5, 95.5
≥ 70% HR_{max}		14.9	24.5	0.0, 72.5	47.4	33.4	0.0, 94.5
≥ HR@VT	Hard	74	25.4	15.8, 99.0	91.5	22	6.1, 100
≥ 50% HR_{max}		95.2	6.8	82.4, 100	97	7.1	73.7, 100
50% < 70% HR_{max}		60.5	32.3	4.5, 99.1	28.4	33.9	0.0, 97.4
≥ 70% HR_{max}		34.7	35.8	0.0, 95.5	68.5	34.4	1.3, 100

n = 19 for easy-level DC; n = 17 for hard-level DC; n = 18 for KF. Range = min, max.

bpm, beats per minute; DC, Dance Central Spotlight; HR_{max}, maximum HR = 220 − age; HR_{peak}, peak HR during cardiopulmonary exercise stress testing; KF, Kung-Fu for Kinect; min, minimum; max, maximum; SD, standard deviation; VT, ventilatory threshold.

an aspect of what makes a game fun and could potentially result in increased player engagement.[29]

Second, some of the movements were difficult to replicate. So, participants occasionally put in minimal effort. When this occurred for physically intense movements, the participants who skipped those movements were likely to have a lower HR. Participants were also penalized for not performing the movements correctly. This penalty impacted player engagement, as they were unable to replicate the movements despite their best efforts. This result is important as studies have found that children are not interested in playing games that are either too difficult or too easy for them.[30]

Third, some of the songs were intentionally played on the easy difficulty levels, and others on harder levels of difficulty specifically designed for exercise. Given that participants differed in the amount of effort required to reach their HR@VT, the easy levels provided MVPA to some but not others. Participants also spent more time playing on the easy levels in DC compared to KF due to the more difficult learning curve in DC preventing game progression.

KF gameplay consistently elicited PA. Even playing on the easy levels resulted in at least MPA, and in some cases even VPA. Participants' gameplay style also differed. Some took advantage of the entire physical play area whereas others remained confined to a small area. Some punched, jumped, and performed high kicks, whereas others used only their arms to punch and occasionally kicked. KF seemed to provide at least MPA regardless of how it was played.

PA game design elements

DC could not reliably provide MVPA because of some inherent design problems. Although it was possible for players to intentionally "cheat" the game, cheating could also be unintentional. Each song varied in how much PA was required to progress. Thus, selecting your preferred songs may result in reduced PA simply by chance. In addition, certain moves designed to be physically intense could be unintentionally circumvented by performing minimal movements that the game interpreted to be correct. In contrast, some movements were too difficult for players to

Table 5. Summary of the game engagement and experience questionnaires

	Game					
	Favorite		DC		KF	
Positive/negative enjoyment measure	Mean	SD	Mean	SD	Mean	SD
Positive						
Engagement*	1.82	0.67	0.95†	0.7	1.39	0.37
Competence*	3.11	0.59	1.99†	1.17	2.53	1
Immersion*	2.76	0.94	1.19†	1.18	2.47	1.06
Flow*	2.1	1.08	1.08†	0.94	1.56	0.87
Challenge*	1.72	1.08	1.31	0.95	1.76	0.73
Positive affect*	3.51	0.42	2.1†	1.46	3.12	0.82
Negative						
Tension/annoyance‡	0.88	1.04	0.82	0.67	0.96	0.59
Negative affect‡	1.04	0.9	1.42	0.78	1.07	0.46

n = 19, except for DC, n = 18, and for KF, n = 16 (for KF Engagement n = 17).

DC, Dance Central Spotlight; Favorite, subject's personal favorite; KF, Kung-Fu for Kinect; SD, standard deviation.

* A score of 4 represents the most-positive experience.

† $P \leq 0.05$ vs Favorite (repeated-measures analysis of variance with Bonferroni pairwise testing).

‡ A score of 0 represents the least-negative experience.

complete at all and could have resulted in players selecting easier songs.

KF had 2 significant design problems. First, it required players to perform certain actions that they had difficulty doing. The effect of this issue was seen in participants who ended the gaming session early because they could not advance through the game as a result. Second, KF has relatively limited content and is more likely to be successful at providing MVPA only for the short term. As content is exhausted, players would likely migrate back to their favorite games. In contrast, KF avoided the design problem associated with DC of needing to be played in a particular way in order to consistently reach at least MPA.

Enjoyment of the AVGs

Although playing AVGs has been shown to be effective at eliciting MVPA, their long-term success at modifying behavior to increase PA has proved less so. The augmented reality game Pokémon GO made great strides in getting a large population of inactive individuals outside and walking.[31,32] Unfortunately, this success was short-lived.[33] Two studies reported that after ~30-40 days, the number of steps taken was back to pre-game levels,[34,35] likely due, in part, to a loss of interest in the game.[18]

Having fun is the most cited reason for engaging in PA, and greater levels of enjoyment have been associated with increased energy expenditure and duration of game play.[36,37] Thus, identifying what makes an AVG fun and engaging is important for good game design.[38] Several motivation frameworks, such as flow theory[39] and self-determination theory,[40] have been applied to help understand what makes something enjoyable. Self-determination theory examines the extrinsic and intrinsic motives for acting, and how they relate to well-being.[40,41] The underlying concept is that activities bolster greater intrinsic motivation based on satisfying 3 fundamental needs: competence, autonomy, and relatedness.[42] When applied to video gaming, competence is the need for challenge and feeling effective at game play (ie, self-efficacy); autonomy is choice, such as what and how to play; and relatedness refers to game-related social interactions, both within and outside of the game.[15] So far, current AVGs have failed to adequately meet all of these needs.[43]

Although, overall, DC was not considered "fun" relative to the participants' favorite games, some of the participants did have fun playing it and indicated that a similar game, *Just Dance* (Ubisoft Entertainment, San Francisco, CA), was one of their favorites. This finding provided additional insight into the variability of what children find fun and is an important consideration. In contrast, participants found playing KF fun, but it is unlikely to be feasible for long-term game play given the lack of content. Offering new AVGs, or the regular addition of new content, may help address these problems and make AVGs more viable as a component of long-term lifestyle change.

Clinical practice implications

Encouraging and promoting the recommended levels of PA in children should be a goal of every clinic. However, we are not recommending that clinicians advocate playing video games in lieu of outdoor activities, and it should be considered a last-resort effort or a means to augment existing PA levels. Given that children are already playing video games regularly, often for long periods of time, AVGs provide an avenue to incorporate more PA into their lifestyle. This approach is not ideal, but youth culture is rapidly changing, and as a result, we must adapt and explore all options in the battle against sedentarism.

Study limitations

Cycle ergometry is known to elicit a lower maximal HR in children compared to other modes of CPET, such as a treadmill, due to limb fatigue. As a result, it is possible that the HR@VT values used as the cutoff threshold for MPA are lower than those that would result from using a treadmill-based test. Thus, the resulting levels of PA may be overestimated. However, we are confident that the impact of this possibility is limited, as subjects were strongly encouraged to continue exercising until a minimum respiratory exchange ratio of ≥ 1.0 was reached. Although 3 subjects did not quite reach this minimum (respiratory exchange ratios = 0.97, 0.97, and 0.98; two of them were also the participants that did not play both games), we do not believe this had a large impact on the results of the study.

The age range of the subjects may have been too broad with respect to gaming preferences. Although there was some age overlap between the reported favorite games, the data suggest that the type of preferred game may differ based on subject age. Younger subjects appeared to prefer more creative type games, whereas older subjects reported liking more action-oriented games. A similar argument possibly can be made for gender, but our results were too limited to explore that, especially considering that there may be an interaction between age and gender. Having additional participants or focusing on a narrower age range may have provided some additional insight into gaming behaviour and how this influenced the interaction and evaluation of the study AVGs. We also evaluated only 2 AVGs that were chosen somewhat subjectively. Offering a greater variety of games may have resulted in more overall MVPA and enjoyment due to player autonomy and ability to choose the game. Unfortunately, given the limited resources, examining this possibility was beyond the capability of the study.

It also would have been informative to gauge the long-term effectiveness of the AVGs to provide adequate MVPA by having additional gaming sessions over time. This measure is important because self-efficacy, or the confidence one has in successfully playing a game, is important for gameplay adherence. For a game that is initially difficult to play, such as DC, self-efficacy should improve over time. On the other hand, the construct of flow, which includes a balance between gameplay being too easy and too difficult, would likely have been important for KF. Given that KF was not as difficult to play, it may have become too easy for players after multiple sessions and resulted in a loss of interest. These are important factors, the effects of which can be captured only through multiple gaming sessions.

Conclusions

This study identified how some games can consistently elicit MVPA over the short term, some key elements of good AVG design, as well as several design limitations. Most children spend more than the recommended time playing video games rather than engaging in outdoor activities. Although outdoor PA is preferable, adding active components to all video games would provide at least adequate levels of PA. Implementation of government policies and a PA rating system would be extremely beneficial given the serious and increasing prevalence of the lack of adequate PA in children.

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Disclosures

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Supplementary Material

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