Feasibility of Using Active Video Gaming as a Means for Increasing Energy Expenditure in Three Nonambulatory Young Adults With Disabilities

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Objective: To examine the feasibility of adapting active video games (AVGs) for nonambulatory wheelchair users at functionally diverse levels and to examine these AVGs as a method for increasing energy expenditure (EE) for 3 young adults with severe (SEV), moderate (MOD), and no upper extremity limitation (NL).

Design: Case study.

Setting: Residential special education school for youth and young adults with physical disabilities.

Participants: Two young adults with spastic cerebral palsy (SEV, MOD) and one young adult with spina bifida (NL). All participants were nonambulatory wheelchair users.

Methods: Each participant performed Wii bowling and tennis and an adapted upper extremity version of a Dance Dance Revolution (DDR) game pad.

Main Outcome Measurements: EE was measured through indirect calorimetry (VO_2). Heart rate data were collected with the use of a Polar Heart Rate Monitor.

Results: SEV and MOD participants showed a higher percentage increase in EE for the Wii games (SEV, 25.6%; MOD, 30.8%) compared with DDR (SEV, 10.8%; MOD, 29.1%), whereas the participant with NL had a greater EE increase for the DDR (173.5%) compared with Wii (59.5%).

Conclusions: AVGs showed clinically significant increases in EE for all 3 participants and can be performed by nonambulatory wheelchair users ranging from those with NL to those with SEV upper extremity limitation with the appropriate adaptations.

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INTRODUCTION

National physical activity recommendations for youth include an hour or more of physical activity daily [1]. Unfortunately, achieving an hour a day of physical activity for most youth with disabilities is extremely difficult, resulting in very high rates of physical inactivity [2-6]. A major reason for the disparity in physical activity between youth with and without disabilities is the lack of accessible and engaging options [2,3]. Barriers that limit exercise options for youth with disabilities within school and community environments include lack of trained staff to accommodate activity adaptations and inaccessible playground environments for wheelchair users, such as grass surfaces [3].

Active video games (AVGs) recently have grown in popularity among nondisabled youth and adults [7-12]. These games (also known as "exergaming") have been explored as a way of increasing physical activity and potentially addressing the obesity problem in nondisabled populations [13]. However, to date, limited research has been conducted on the use of AVGs in youth and young adults with disabilities to address these same issues. This limited research may be attributable, in part, to the inaccessibility of some of these games for wheelchair users. Several of the games involve standing and are designed for both upper and lower extremity involvement. Adapting the games for nonambulatory users and examining their feasibility for increasing energy expenditure (EE) among this population offers a possible solution to traditional exercise barriers.

Two popular AVGs used with nondisabled populations include the Nintendo Wii and the Konami Dance, Dance Revolution (DDR). Lanningham-Foster et al [11] examined EE in

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nondisabled youth who played the Wii boxing game and concluded that the game produced a modest increase in EE but would only yield a fitness-enhancing effect if played for extended periods. Unnithan et al [12] evaluated the energy cost for DDR play among a sample of 10 overweight and 12 nonoverweight children and found that the average absolute volume of oxygen utilization (VO_2) was significantly higher in the overweight group compared with the group that was not overweight. However, no significant difference in the average energy cost was found when VO_2 was controlled for fat-free mass.

AVGs have been used in a small number of studies involving short-term rehabilitation in people with spinal cord injury [14-16], stroke [17], burns [18], spina bifida [19], and cerebral palsy [20,21]. However, to date only 2 studies have been published in which authors examined the EE of AVGs in people with disabilities [22,23]. Hurkmans et al [22] reported that Wii Sports tennis and boxing provided moderate intensity exercise for ambulatory adults with bilateral spastic cerebral palsy. More recently, Hurmans et al [23] found that playing Wii Sports tennis and boxing also resulted in moderate intensity exercise in a group of chronic stroke patients.

Inaccessible features of earlier versions of AVG technology included floor game pads (ie, DDR) and hand controllers that were hard to grip for people without full hand function (ie, people with upper level spinal cord injury or cerebral palsy). Given the limited opportunities for nonambulatory youth and adults with disabilities to participate in various recreational sports and leisure activities, the primary aims of this study were to examine the feasibility of AVGs for nonambulatory wheelchair users at functionally diverse levels and to examine these AVGs as a method for increasing EE for 3 young adults with severe (SEV), moderate (MOD), and no upper extremity limitation (NL).

METHODS

Participants

Three young adults with physical disabilities from a residential special education school for youth and young adults in a large metropolitan city were selected for the study. All participants were nonambulatory wheelchair users with differing levels of upper extremity function. Participant 1 (SEV; severe limitation) was a 21-year-old woman with spastic tetraplegic cerebral palsy and bilateral upper extremity limitations. Participant 2 (MOD; moderate limitation) was a 19-year-old man with spastic diplegic cerebral palsy and unilateral upper extremity limitations. Participant 3 (NL; no limitation) was a 21-year-old man with spina bifida and no upper extremity limitations. Both participants with cerebral palsy used power wheelchairs, and the participant with spina bifida used a manual wheelchair. To enroll in the study, participants had to meet the following upper extremity movement criteria: (1) 90° of active shoulder flexion; (2) full grip in at least one hand; and (3) active elbow flexion and extension within functional limits. Exclusion criteria were as follows: (1) ambulatory status; (2) medical contraindications to exercise; (3) cognitive limitations that prevented the participant from following directions; and (4) the inability to speak or understand English. Written informed consent was obtained from all participants. The institutional review board at the University of Illinois at Chicago approved this study.

Procedures

The gaming and testing activities occurred at a residential school for students and young adults with disabilities. A private room was arranged with a 32-inch television monitor, a gaming activity table, and portable metabolic unit (VMax Encore 29C unit; Carefusion, Yorba Linda, CA). Each participant performed the AVGs individually and in separate sessions.

Participants completed three 10-minute bouts of each of the following activities in separate sessions: Wii Sports tennis and bowling (Nintendo, Redmond, WA) and DDR via the use of adapted upper extremity game pad (Konami Digital Entertainment, Tokyo, Japan). All participants previously had been exposed to the Wii Sports games at home or with friends, but none had ever played DDR because they were nonambulatory and the game was designed for use with the lower extremities. The adapted upper extremity game pad for the DDR system was designed and pilot tested by the authors. This table-top version included a set of pressure sensors under the game pad grid that allowed participants to perform the dance routines with their arms by hitting the appropriate directional arrows with their arms instead of their legs while following the directional arrows on a television monitor in front of them.

After the participants were instructed on how to play each AVG and had a chance to practice using the DDR adapted game pad, a mouthpiece attached to the headgear was placed on the individual to measure resting EE (VO_2, $mL.kg^{-1}min^{-1}$) for 5 minutes via the use of indirect calorimetry. Resting heart rate (HR; $b.m^{-1}$) was measured with a Polar heart rate monitor (Polar Electro Inc, Lake Success, NY). After we established their baseline resting EE and resting HRs, each participant performed the selected AVG for 10 minutes (Wii or DDR). Heart rates and VO_2 were monitored continuously during each activity.

Gaming Activities

Wii Sports tennis and bowling and DDR were played individually by each participant for 10 minutes per activity. Each activity was performed on separate days.

Wii Sports. To reduce the lag time between each game (Wii games are arranged by level of difficulty with a time delay

Figure 1. Participant playing the Wii bowling game while volume of oxygen utilization is measured.

between each level), the system was set on a continuous loop so that the games would restart immediately after ending until the 10-minute protocol was completed. Participant 1 had limited hand movement bilaterally (SEV) and had difficulty using both controllers but was able to use one controller (instead of the standard 2 controllers for use with each hand) with the dominant hand. Participant 2 had unilateral limited hand movement (MOD) and was able to fully use one controller with the dominant hand. Figure 1 shows participant 3 (no upper extremity limitation) playing the Wii bowling game while wearing the VO_2 testing headgear.

DDR. Each participant was asked to select 10 songs from a dance playlist before beginning the 10-minute activity so that songs could be selected quickly to promote continuous activity. The game was set in "workout mode," and the adapted table top version of the game pad was set on an adjustable table that allowed room for the wheelchair to fit underneath. Participants were able to reach across the table to strike the pad according to the arrow indicators on a television screen set up on the opposite side of the table. The height and angle of the table and pad placement were adjusted for each participant to allow for full access to all arrow buttons.

RESULTS

Table 1 presents the results for each of the AVGs by EE and HR. For Participant 1, DDR increased EE by 10.8% and Wii increased EE by 25.6%. For participant 2, DDR increased EE by 29.1%, and Wii increased EE by 30.8%. For participant 3, DDR increased EE by 127.3%, and Wii increased EE by 59.5%. For participant 1 (SEV), DDR increased HR by 14.0%, from 83.3 to 95.0 beats.min^{-1} (SD 7.2, 6.7), and Wii increased HR by 9.7%, from 86.3 to 94.7 beats.min^{-1} (SD 1.5, 6.1). For participant 2 (MOD), DDR increased HR by 22.7%, from 78.7 to 96.6 beats.min^{-1} (SD 2.1, 4.2), and Wii increased HR by 32.7%, from 74.3 to 110.3 beats.min^{-1} (SD 3.2, 4.4). For participant 3 (NL), DDR increased HR by 23.7%, from 87.0 to 114.0 beats.min^{-1} (SD 3.2), and Wii increased HR by 21.5%, from 73.5 to 89.3 beats.min^{-1} (SD 5.0, 7.4).

DISCUSSION

The primary aims of this feasibility study were (1) to determine whether AVGs can be adapted for nonambulatory wheelchair users with varying levels of upper extremity function and (2) to examine whether playing these games from a sitting position would result in EE increases significant enough to recommend for future use by rehabilitation researchers and practitioners who work with these populations. The results of the first aim demonstrated that AVGs can be adapted for nonambulatory young adults with a range of upper extremity limb function. The second aim demon-

Table 1. *Participant energy expenditure and heart rate by activity*

	Resting EE mL.kg^{-1}min^{-1} (Mean ± SD)	Active EE mL.kg^{-1}min^{-1} (Mean ± SD)	Increase (%)	RHR Beats/ min	AHR Beats/ min	Increase (%)
Participant 1* (SEV)						
DDR	3.85 ± 0.3	4.20 ± 0.5	10.8	83.3 ± 7.2	95.0 ± 6.7	14.0
Wii	3.85 ± 0.3	4.90 ± 0.5	25.6	86.3 ± 1.5	94.7 ± 6.1	9.7
Participant 2 (MOD)						
DDR	3.85 ± 0.2	5.60 ± 1.1	29.1	78.7 ± 2.1	96.6 ± 4.2	22.7
Wii	3.85 ± 0.4	5.25 ± 1.0	30.8	74.3 ± 3.2	110.3 ± 4.4	32.7
Participant 3 (NL)						
DDR	3.50 ± 0.3	7.35 ± 0.6	127.3	87.0†	114.0 ± 3.2	23.7
Wii	4.20 ± 0.4	6.65 ± 1.0	59.5	73.5 ± 5.0	89.3 ± 7.4	21.5

EE = energy expenditure; SD = standard deviation; RHR = resting heart rate; HR = heart rate; AHR = activity heart rate; SEV = severe upper extremity limitation; DDR = Dance, Dance Revolution; MOD = moderate upper extremity limitation; NL = no upper extremity limitation.

*Participant 1 = severe upper extremity limitation; participant 2 = moderate upper extremity limitation; participant 3 = no upper extremity limitation.

†Mean and SD not available because of instrument malfunction.

strated that clinically meaningful increases in EE and HR were obtained for all participants.

Given the enormous challenges associated with participation in physical activity expressed by people with disabilities [2,3,24,25], the upper extremity game pad adaptations that we developed address these usability challenges by allowing nonambulatory young adults to play the DDR. Despite these initial promising results, the pilot nature of this work must be acknowledged, and further testing on larger samples of similar groups must be undertaken to be able to generalize these findings. Therefore, this study provides important basic information on the feasibility and accessibility of these AVG options for this population, but further exploration is required.

To date, limited research has been performed on the use of AVGs for promoting physical activity in youth and adults with disabilities. Likewise, no research has been performed on the exposure of these activities by range of upper extremity function or use of an adaptation to allow participation (ie, DDR from a seated versus standing position). Although in a few recent studies authors have examined AVG as a tool for rehabilitation [14-21], no studies have been published in which authors have used AVGs to examine EE in nonambulatory youth and young adults with mobility disabilities [7]. The current study is unique in that it examined EE and the feasibility of playing AVGs from a seated position in 3 individuals with various levels of upper extremity function.

To date, the only 2 known published studies examining AVG EE for people with disabilities are by Hurkmans et al [22,23], who tested ambulatory adults with cerebral palsy who were able to play Wii games from a standing position, and adults with chronic stroke who played Wii games in sitting and standing positions. Our study is the first to add to the potential benefit of AVGs for nonambulatory populations.

Although the AVG EE and HR values were fairly low in our participants, recent research supports the use of low-intensity activity for promoting health. Owen et al [26] found that any form of EE greater than rest, including standing versus sitting, can have substantial benefits to health improvement. The increases in EE and HR observed in our 3 participants were similar to performing low-intensity exercise. This increase can be an important part of overall daily EE, especially in nonambulatory youth and young adults with disabilities who have limited or no access to physical activity and have low EE levels across the day.

Although AVGs have the potential to supplement existing exercise programs with enjoyable alternatives, a few challenges need to be addressed in future research. Some of the gaming options need to be adjusted to offer individual modifications for usability and reachability. For example, increasing the DDR game pad's button sensitivity and offering a variety of game pad sizes could ensure that people with a variety of hand and arm function could reach and strike the correct buttons. Other limitations involve the nature of the gaming software. Specifically, the episodic play that is inherent in the Wii software often is tied to performance-based advancement (ie, hitting an object a certain number of times accurately will advance to the next level of play). Likewise, some of the games have gaps in movement continuity while they are resetting for the next activity. This episodic play is not as evident in the DDR games because they offer a "workout" mode that allows for continuous play through a song, which can be replayed or reset immediately after it ends. Future use of continuous-play gaming systems could be tested for feasibility and usefulness among larger samples of nonambulatory populations to offer a variety of game choices.

Our findings suggest that AVGs can be used in a sitting position by wheelchair users to promote physical activity. Future research should examine whether AVGs are effective for promoting fitness or reducing obesity. Other games with extensive and continuous bilateral arm movement also could be tested (eg, Wii boxing). Many options exist for examining the effects of social interaction related to game play, and future research could explore competitive play involving people with low and in some cases, moderate levels of and without disabilities engaged in these gaming activities as a way of increasing intensity and duration for exercise.

CONCLUSION

This feasibility study supports the use of AVGs in nonambulatory individuals with disabilities who have a range of upper extremity limitations using an adapted game pad for playing DDR and continuous-loop options on the Wii system to minimize breaks. All 3 individuals were able to participate in all gaming activities. Researchers and practitioners should consider selecting and programming games that involve a greater amount of upper extremity movement (eg, basketball and heavy bag boxing), along with using light, Velcro-attached arm weights to increase the workload while playing AVGs to determine whether higher levels of EE can be achieved. Finally, further research is needed with larger homogeneous samples of nonambulatory wheelchair users to determine exercise intensity of various AVGs for a variety of games that provide continuous movement capability.

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