Energy Expenditure and Enjoyment During Active Video Gaming Using an Adapted Wii Fit Balance Board in Adults with Physical Disabilities

Background: Individuals with physical disabilities have fewer opportunities to participate in enjoyable physical activity. One option for increasing physical activity is playing active video games (AVG), however, many are inaccessible or offer limited play options.

Objective: To examine energy expenditure and enjoyment in adults with mobility impairment during AVG play using off-the-shelf (OTS) and adapted versions of the Wii Fit balance board.

Methods: During visit 1, participants completed a functional assessment and familiarization period. For visit 2, metabolic data were collected during a 20-minute baseline and four 10-minute bouts of Wii Fit Plus game play, two bouts on each of the boards. During rest participants completed the Physical Activity Enjoyment Scale (PACES). Statistical analyses were computed using SPSS. Data were analyzed separately for individuals who were able to play standing on both boards (StdStd), those who could not play standing on the OTS board, but were able to play standing on the adapted board (aStd), and for those who could only play seated on the OTS board (aSit).

Results: Data were collected for 58 participants (StdStd, n=17; aStd, n=10; aSit, n=31). Sample included 31 men, 27 women with a mean age of 41.21 (+12.70) years. Energy expenditure (METs) during game play was significantly greater than rest for all players. Only 17 participants (StdStd group) were able to play using OTS board. During game play on adapted board average MET values for the two game sets were: aSit = 2.261±0.718, 2.233±0.751 kcal/kg/hour; aStd = 3.151±1.034, 2.990±1.121; StdStd = 2.887±0.823, 2.881±0.898. For game play on the adapted board, self-reported rating of perceived exertion (RPE) on a 0-10 scale suggested greater exercise intensity levels, with median RPE scores ranging from moderate (3) to very hard (7). PACES scores indicated that all players enjoyed using the adapted board with median scores of 4 on a 5-point scale.

Conclusions: The adapted Wii Fit balance board provided an opportunity for those with mobility impairments, including wheelchair users, to engage in AVG. All participants were able to utilize the adapted controller and enjoyed the AVG activity. Although average MET values achieved during AVG represented light intensity exercise (<3 METs), 16% of seated participants and 41% of standing participants achieved moderate intensity (3-6 METs) exercise on at least one of the games. Factors not accounted for that may have influenced intensity of exercise include: 1) game selection, 2) limited familiarization period, and 3) discomfort wearing COSMED system for oxygen consumption measurement. Accessible AVG controllers offer an innovative approach to overcoming various barriers to participation in physical activity. Next steps include assessment of an AVG intervention using an adapted board gaming controller on health and fitness outcomes.

Trial Registration: ClinicalTrials.gov NCT02994199

KEYWORDS: Exergaming; Video games; Exercise; Physical activity; Disability; Energy expenditure; Enjoyment
INTRODUCTION
Physical inactivity is significantly higher in people with disabilities due to fewer opportunities and countless barriers to engaging in leisure-time physical activity [1-7]. Lack of transportation, inaccessible fitness facilities, absence of staff trained in working with people disabilities, and boredom associated with using standard exercise equipment all contribute to higher sedentary behaviors in this population [1-7]. Replacing sedentary behaviors with active video games (AVGs) holds promise as a way to reduce those barriers and increase leisure-time physical activity in people with disabilities [8-12]. Moreover, AVGs have been described as having the potential to be a “gateway experience” to physical activity, suggesting that such games may open the door to interest and participation in other forms of physical activity for persons with disabilities [10].

Active video games (AVGs), also called “exergames”, are video games that require actions of large body parts (like trunk or upper or lower extremity) or the whole body to control game play as opposed to games that only require hand or finger movements to play. Gaming systems that have AVG capability include the Nintendo Wii, Sony PlayStation Move, and the Microsoft Xbox Kinect. Depending on the design of games and control systems used, AVGs have been shown to be an enjoyable leisure-time physical activity option to replace sedentary screen time [13-17], with the potential to increase cardiorespiratory fitness and enhance balance and functional mobility [15,16,18-28]. Furthermore, AVGs show promise as an enjoyable physical activity alternative for individuals with disabilities, in large part because they overcome certain common barriers to physical activity such as transportation and access to adequate facilities [10,11].

Important to determine is whether the level of physical activity offered by AVGs is high enough to achieve the same fitness and health benefits offered by traditional exercise. Several studies have reported increases in energy expenditure sufficient for maintaining and improving health in individuals with mobility impairments such as cerebral palsy (CP) [12,29-32], spinal cord injury (SCI) [33,34], and stroke [29,35-37]. A literature review by Deutsch and colleagues [29] sought to determine whether evidence existed to support the use of video games for the promotion of fitness and wellness for adults post-stroke (moderate severity) and those with CP (mild severity). It was found that both groups are able to achieve moderate energy expenditure playing Nintendo Wii, Sony Playstation, and Xbox Kinect games. In another study done by Hurkmans et al. [31], adults with CP who were able to stand without support were asked to play Wii Sports tennis and boxing while their energy expenditure was measured using a portable gas analyzer. The results of the study found that participants achieved moderate intensity exercise during both games. A similar study done by Robert et al. [32] evaluated exercise intensity in children with CP who were able to stand and children without CP. This group discovered similar exercise intensity levels for both groups, suggesting that children with CP who are able to play video games while standing can obtain exercise-related benefits that are similar to those obtained by children without CP. A systematic review by Mat Rosly et al. [33] found that adults with SCI were able to achieve the recommended moderate-to-vigorous physical activity guidelines proposed by the American College of Sports Medicine (ACSM). A case study done with two young adults found that persons with SCI are able to achieve moderate intensity level heart rates when playing boxing on the Nintendo Wii while seated.[34] Furthermore, when compared with conventional boxing, Rosly et al. [38] found that individuals with SCI were able
to achieve the same moderate intensity level when playing exergame boxing. Another study determined that post-stroke individuals were able to play Wii tennis and Wii boxing at a moderate intensity level, classified using the ACSM and the American Heart Association guidelines (3-6 METs) [35]. A different study compared the performance of playing Nintendo Wii and Sony Xbox 360 in adults post-stroke and individuals without a disability [36]. Kafri et al. [36] not only found that AVG gameplay while standing produced moderate intensity exercise levels, but post-stroke participants also approached anaerobic metabolism when playing in the sitting position.

Although AVGs hold promise as an opportunity to increase physical activity in people with disabilities, physical limitations such as decreased motor control, range of motion, muscle strength, ambulatory status, and balance limit AVG accessibility for a large portion of this population [10,12,39]. For example, the majority of the studies noted above for individuals with CP and post-stroke were comprised of individuals with mild to moderate mobility impairments who were able to play the AVGs without adapted equipment. Likewise, limited AVG play options are available for people who are unable to stand, have balance problems or poor motor control, or cannot use their lower body to perform game movements [10]. For instance, floor pad game controllers used by AVGs (eg, Dance, Dance Revolution; Wii Outdoor Challenge) have obvious accessibility limitations. Though motion controlled AVGs offer slightly greater access, accelerometer-based hand controllers like those used by the Sony PlayStation Move and Nintendo Wii platforms often require rapid and precise movements for successful play, and AVGs using the camera-based controller of Microsoft Kinect typically require the player to be standing for proper game function. For this reason, AVG adaptations to game controllers are essential in order to offer people with disabilities options for using AVGs for moderate-to-vigorous exercise in environments such as their home and communities [11]. Offering adapted controllers for AVG play to people with disabilities is also a necessary first step toward examining their feasibility for increasing energy expenditure.

Development of adapted game hardware not only offers an innovative approach to overcoming numerous barriers to exercise in people with disabilities, but it also provides an enjoyable form of exercise to this population. Successful adaptations to game controllers and interfaces that allow people with disabilities to play video games have been developed [40-43], however, there has been limited research and development efforts focused on improving accessibility of gaming controllers for use with AVGs. The Rehabilitation Engineering Research Center on Interactive Exercise Technologies and Exercise Physiology for People with Disabilities (RERC RecTech) at the University of Alabama at Birmingham (UAB)/Lakeshore Foundation Research Collaborative examined the accessibility of video game controllers including the Wii balance board system. Data regarding game play, participants’ ability to use the controllers, user feedback, and research staff qualitative observations indicated that the Wii balance board was in need of adaptation for successful game play. This data was fed to the engineering team for development of an adapted gaming balance board.

The primary deficiencies in the balance board included a small platform area (19.5 inches x 12 inches), the inability to use a stabilization assistive device (ie, walker, cane), and the requirement of a full range of motion for responsive gameplay. To address these deficiencies and increase accessibility, the balance board was redesigned to feature a much larger platform area (40 inches x 38 inches), built-in lateral stabilization supports (ie, handrails), and adjustable
sensitivity for center of balance support [44]. The adaptations were selected to not only enable wheelchair users to use the adapted balance board, but to make it a universal device with enhanced safety for all users.

Usability of the OTS and adapted balance board controllers were evaluated in individuals with mobility impairments using the System Usability Scale (SUS) [44]. The user-centered design approach resulted in an adapted version of the WFBB, which met the needs of a variety of users. Results demonstrated a successful adaptation and increase in usability of the adapted balance board, with the adapted board scoring significantly greater mean SUS scores when compared to the SUS scores of the off-the-shelf board.

Despite the fact that a variety of successful adaptations to AVG game controllers and interfaces that allow people with disabilities to play AVGs have been developed by rehabilitation engineers and assistive technology specialists, there have been limited research and development efforts focused on measuring energy expenditure. Modifications of these game controllers must be not only successful in allowing people with disabilities to play AVGs, but they must also successfully allow people with disabilities to achieve levels of energy expenditure that are similar to the levels of those without disabilities.

The purpose of this study was to examine energy expenditure and enjoyment in adults with physical disabilities, specifically those with mobility impairments (ie, unable to stand, balance issues, poor motor control, unable to use lower extremity for gameplay), during AVG play using OTS and adapted versions of the Wii Fit balance board.

METHODS

Design and Setting
The study was conducted in the Exercise and Sport Science Laboratory at Lakeshore Foundation (Birmingham, Alabama, USA), a community organization that provides physical activity, sport, and recreation opportunities for individuals with physical disability and chronic health conditions. For the purposes of this study, participants came to the lab a total of 3 times generally within a three-week period.

Participants
Eligibility criteria included 18+ years of age, a confirmed diagnosis of lower extremity mobility limitation (eg, spina bifida, CP, muscular dystrophy, 1 year post SCI, multiple sclerosis, stroke, or limb loss) with partial or full use of upper extremities and use of an assistive device (eg, cane, walker, wheelchair) or problems with gait, balance, and/or coordination. Participants were excluded if they had an unstable cardiovascular condition, a visual impairment that interfered with playing video games, or weighed over 350 lbs (159 kg) including their assistive device.
Procedures

Visit 1
During the first visit, informed consent/assent was obtained, and demographic and health history information was documented. An assessment of each participant's functional ability was conducted as described below. In addition, participants were familiarized with the equipment (Cosmed K4b2 portable metabolic system) used for the study and the video games that would be played during subsequent visits. Participants played a portion of or the entire game for all those that were used during testing.

Functional Assessment
For the assessment of physical functional that was conducted during the first visit, each participant performed 18 functional movement tasks from the International Classification of Functioning, Disability and Health (ICF) [45,46]. Participants completed each task individually and were scored according to their difficulty in completing the task on a scale ranging from 0 to 4. As defined in the ICF manual, the scoring was as follows: 0 = “No difficulty,” 1 = “Mild difficulty,” 2 = “Moderate difficulty,” 3 = “Severe difficulty,” and 4 = “Complete difficulty.” The specific ICF tasks selected for use in this study were based on a consensus among the research staff as to which mobility activities listed in the ICF had the potential to be required for AVG play (eg, standing, reaching, throwing, and jumping) based on observations during the pilot testing. Scores on each of the 18 tasks were added together as a composite to represent participant physical function [9]. A lower composite score indicated greater functional ability on the selected tasks.

In addition to the functional assessment, participants also completed a series of questions from the HealthMeasures resources [47], which were used as an assessment of the individual's own perspective regarding their functional ability. Questions came from the Patient Reported Outcomes Measurement Information System (PROMIS®). The series comprised of questions from PROMIS SFv1.0 Physical Function 20a and PROMIS SFv1.0 Physical Function Samples with Mobility Aid. Questions asked participants how difficult a variety of daily tasks (ie, vacuuming, yard work, walking, bathing, etc.) were to complete (5 point scale, “without any difficulty” to “unable to do”, 14 questions), whether their health limited them in their ability to complete certain activities (ie, carry groceries, strenuous sports, walking a mile, etc.; 5 point scale, “not at all” to “cannot do”; 6 questions), and their ability to stand and move with and without support (“yes” or “no”, 1 question; 5 point scale, “without any difficulty” to “unable to do”, 10 questions).

AVG Play
The subsequent visit consisted of exercise testing during video game play. Upon arrival, participants were set up with the Cosmed K4B2 portable metabolic system and a Polar heart rate monitor to assess pulmonary gas exchange and indirect calorimetry. Data collection began with a 20-minute rest period to measure resting energy expenditure. For the rest period participants sat quietly with no speaking or distractions besides light reading of a magazine or
viewing their cellular phone. Next, gameplay began with continued gas exchange and heart rate data collection.

The Nintendo Wii video game console and a video game CD for the Wii Balance Board (Wii Fit Plus, Nintendo) were used for gameplay. Two game sets were created as outlined in Table 1. Game Set A included Rhythm Kung Fu, Rhythm Parade, Obstacle Course, and Birds Eye Bullseye. Game Set B included Island Cycling, Penguin Slide, Hula Hoop, and Ski Slalom. Selected games were chosen in an effort to provide moderate level physical activity during gameplay.

**Table 1.** Description of each game played using the OTS and adapted balance board.

<table>
<thead>
<tr>
<th>Mini Game</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wii Fit Plus: Game Set A</strong></td>
<td></td>
</tr>
<tr>
<td>Rhythm Kung Fu</td>
<td>The participant follows the Kung Fu movements of Mii characters in time with the rhythm. Movements include left and right punches, two hand punches, and left and right kicks.</td>
</tr>
<tr>
<td>Rhythm Parade</td>
<td>The participant marches in place to the rhythm of the parade while directing the parade with arm movements in coordination with the game.</td>
</tr>
<tr>
<td>Obstacle Course</td>
<td>The participant marches in place to run the character through an obstacle course of swinging balls, moving platforms, and jumps.</td>
</tr>
<tr>
<td>Bird’s-Eye Bull’s-Eye</td>
<td>The participant flaps their arms and moves their body to fly through the course landing on targets spread across the map.</td>
</tr>
<tr>
<td><strong>Wii Fit Plus: Game Set B</strong></td>
<td></td>
</tr>
<tr>
<td>Island Cycling</td>
<td>The participant marches in place on the board to pedal the bike throughout the map while capturing flags that are spread out throughout the island.</td>
</tr>
<tr>
<td>Penguin Slide</td>
<td>The participant catches fish by leaning left and right on the balance board to control the Mii.</td>
</tr>
<tr>
<td>Hula Hoop</td>
<td>The participant rotates their trunk/hips in a circular motion on the board to control the Mii hula hooping.</td>
</tr>
<tr>
<td>Ski Slalom</td>
<td>The participant skis down the slope by leaning left and right to control the Mii skier’s course.</td>
</tr>
</tbody>
</table>

Participants first played the two game sets on the OTS gaming board and then played the games on the adapted gaming board. The order of the game sets (Set A, Set B) played was randomly assigned to the participant. Each game set was played for 10 minutes with a rest period of 5 minutes afterwards [9].

At the end of each game set participants provided a rating of perceived exertion (RPE) on a scale from 0-10, with 0 = Not Tired at All to 10 = Very, Very Tired. During rest periods, participants completed a feedback survey that included the Physical Activity Enjoyment Scale (PACES) [48]. The PACES includes 16 statements such as “I enjoyed it”, “It was very exciting”, “I felt bored” and “It was no fun at all”. All items were rated by the participant on a 5-point scale ranging from 1 = “Strongly Disagree,” to 5 = “Strongly Agree”.
Data Analysis

Analyses were performed using the Statistical Package for the Social Sciences (SPSS). For each measure, the mean, standard deviation, median, and interquartile range (IQR) were presented. A Wilcoxon Signed-Rank Test was used to detect any significance between participants’ OTS measures and their Adapted measures.

For each of these analyses, participants were divided into one of three unique groups based on their method of gameplay and level of access: a) Sitting (aSit) - these individuals were seated for gameplay, thereby unable to access the OTS board and played only on the adapted board; b) Standing, adapted board only (aStd) - these players were able to stand, but due to mobility and/or balance issues could not access the OTS board, therefore played only on the adapted board; c) Standing, both boards (StdStd) - these individuals were able to stand for gameplay on both the OTS and adapted boards.

To assess project aims, a series of analyses were conducted. To test whether energy expenditure during gameplay was different than resting energy expenditure (which could be readily taken for granted but was not assumed), resting METs were compared to gameplay METs for each subgroup. In addition, for each subgroup, the change in METs (gameplay – rest) was compared between the OTS and adapted boards. As a subjective rating of energy expenditure, RPE scores were analyzed for both OTS and adapted. To examine enjoyment, PACES scores were analyzed for both OTS and adapted boards for participants who were able to play both games, and for those who could only play using the adapted controller scores were simply reported.

RESULTS

A total of 58 participants (aStd, n = 10; aSit, n = 31; StdStd, n = 17) completed two 10-min bouts of select Wii Fit Plus games on the OTS and adapted boards. The sample included 31 men and 27 women with a mean age of 41.21 (±12.70) years.

Analysis of the metabolic data indicated that energy expenditure (METs) during game play was significantly greater than resting MET values for all players during both game sets on both the adapted and OTS boards (Table 2).

Table 2. Resting and game play energy expenditure (METs) on the OTS and Adapted boards.

<table>
<thead>
<tr>
<th>Play Style</th>
<th>Game</th>
<th>n</th>
<th>Resting METs Mean (SD)</th>
<th>Game METs Mean (SD)</th>
<th>Resting METs Median (IQR)</th>
<th>Game METs Median (IQR)</th>
<th>Wilcoxon Signed Rank P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTS Board</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>aSit</td>
<td>Set A</td>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Set B</td>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>aStd</td>
<td>Set A</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Set B</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>StdStd</td>
<td>Set A</td>
<td>17</td>
<td>1.014</td>
<td>2.839</td>
<td>1.032</td>
<td>2.777</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Unable to utilize controller for gameplay.
When comparing change in energy expenditure (Game play METs – Rest METs) values between the OTS and adapted boards, significant differences (P<0.001) were observed for the participants who played seated, but not those who played standing (Table 3).

**Table 3. Change in energy expenditure (METs) (gameplay – rest) between the OTS and Adapted boards.**

<table>
<thead>
<tr>
<th>Play Style</th>
<th>Game</th>
<th>n</th>
<th>OTS Mean (SD)</th>
<th>Adapted Mean (SD)</th>
<th>OTS Median (IQR)</th>
<th>Adapted Median (IQR)</th>
<th>Wilcoxon Signed Rank P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>aSit</td>
<td>Set A</td>
<td>31</td>
<td>0.000 (0.000)</td>
<td>1.105 (0.564)</td>
<td>0.000 (0.000-0.000)</td>
<td>1.067 (0.685-1.349)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>Set B</td>
<td>31</td>
<td>0.000 (0.000)</td>
<td>1.077 (0.576)</td>
<td>0.000 (0.000-0.000)</td>
<td>0.975 (0.690-1.384)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>aStd</td>
<td>Set A</td>
<td>10</td>
<td>0.000 (0.000)</td>
<td>2.088 (0.712)</td>
<td>0.000 (0.000-0.000)</td>
<td>1.897 (1.607-2.413)</td>
<td>.005</td>
</tr>
<tr>
<td></td>
<td>Set B</td>
<td>10</td>
<td>0.000 (0.000)</td>
<td>1.927 (0.832)</td>
<td>0.000 (0.000-0.000)</td>
<td>1.969 (1.390-2.542)</td>
<td>.005</td>
</tr>
<tr>
<td>StdStd</td>
<td>Set A</td>
<td>17</td>
<td>1.825 (0.508)</td>
<td>1.718 (0.506)</td>
<td>1.696 (1.588-1.979)</td>
<td>1.641 (1.464-1.761)</td>
<td>.113</td>
</tr>
<tr>
<td></td>
<td>Set B</td>
<td>17</td>
<td>1.688 (0.459)</td>
<td>1.763 (0.657)</td>
<td>1.586 (1.434-1.995)</td>
<td>1.534 (1.342-2.038)</td>
<td>.535</td>
</tr>
</tbody>
</table>

As a subjective rating of exercise intensity, RPE values were recorded as shown in Table 4. Mean and median scores are reported for each of the three groups, and for the StdStd group scores were compared between the two boards. For Set A, RPE did not differ significantly between
gameplay on the OTS and Adapted boards. For Set B, RPE values for the Adapted board were significantly higher ($P < .05$) than those for OTS Board.

**Table 4.** Rating of perceived exertion (RPE) following game play on the OTS and Adapted boards

<table>
<thead>
<tr>
<th>Play Style</th>
<th>Game</th>
<th>n</th>
<th>OTS Mean (SD)</th>
<th>OTS Median (IQR)</th>
<th>Adapted Mean (SD)</th>
<th>Adapted Median (IQR)</th>
<th>Wilcoxon Signed Rank P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>aSit</td>
<td>Set A</td>
<td>31</td>
<td>---*</td>
<td>3.710 (2.101)</td>
<td>---*</td>
<td>3 (2.5-5)</td>
<td>---*</td>
</tr>
<tr>
<td></td>
<td>Set B</td>
<td>31</td>
<td>---*</td>
<td>3.871 (2.460)</td>
<td>---*</td>
<td>4 (2-4.5)</td>
<td>---*</td>
</tr>
<tr>
<td>aStd</td>
<td>Set A</td>
<td>10</td>
<td>---*</td>
<td>5.3 (2.263)</td>
<td>---*</td>
<td>3 (2.5-5)</td>
<td>---*</td>
</tr>
<tr>
<td></td>
<td>Set B</td>
<td>10</td>
<td>---*</td>
<td>6 (1.563)</td>
<td>---*</td>
<td>6 (5-7.5)</td>
<td>---*</td>
</tr>
<tr>
<td>StdStd</td>
<td>Set A</td>
<td>17</td>
<td>4.240 (2.488)</td>
<td>5 (3-6)</td>
<td>4.470 (2.625)</td>
<td>6 (2-6)</td>
<td>.590</td>
</tr>
<tr>
<td></td>
<td>Set B</td>
<td>15</td>
<td>4.600 (2.384)</td>
<td>5 (2.5-6)</td>
<td>5.530 (3.270)</td>
<td>7 (2.5-8)</td>
<td>.050</td>
</tr>
</tbody>
</table>

* *Statistic could not be presented because participants from this group were unable to play the OTS board and the measure value could not be logically assumed to be zero.

With regard to enjoyment there were no significant differences in PACES scores between the OTS and Adapted boards (Table 5). Median PACES scores for all conditions was 4, or “agree”.

**Table 5.** Assessment of game play enjoyment based on PACES scores

<table>
<thead>
<tr>
<th>Play Style</th>
<th>Game</th>
<th>n</th>
<th>OTS Mean (SD)</th>
<th>OTS Median (IQR)</th>
<th>Adapted Mean (SD)</th>
<th>Adapted Median (IQR)</th>
<th>Wilcoxon Signed Rank P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>aSit</td>
<td>Set A</td>
<td>31</td>
<td>---*</td>
<td>3.835 (0.756)</td>
<td>---*</td>
<td>4.000 (3.625-4.344)</td>
<td>---*</td>
</tr>
<tr>
<td></td>
<td>Set B</td>
<td>31</td>
<td>---*</td>
<td>3.973 (0.659)</td>
<td>---*</td>
<td>4.063 (3.500-4.517)</td>
<td>---*</td>
</tr>
<tr>
<td>aStd</td>
<td>Set A</td>
<td>10</td>
<td>---*</td>
<td>3.925 (0.640)</td>
<td>---*</td>
<td>3.813 (3.563-4.547)</td>
<td>---*</td>
</tr>
<tr>
<td></td>
<td>Set B</td>
<td>10</td>
<td>---*</td>
<td>3.999 (0.673)</td>
<td>---*</td>
<td>3.902 (3.672-4.547)</td>
<td>---*</td>
</tr>
<tr>
<td></td>
<td>Set A</td>
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<td>-------</td>
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<td></td>
</tr>
<tr>
<td>Std</td>
<td>17</td>
<td>4.125</td>
<td>4.035</td>
<td>4.063</td>
<td>4.000</td>
<td>0.756</td>
<td></td>
</tr>
<tr>
<td>Std</td>
<td></td>
<td>(0.624)</td>
<td>(0.687)</td>
<td>(3.625-4.625)</td>
<td>(3.438-4.813)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set B</td>
<td>17</td>
<td>4.110</td>
<td>3.860</td>
<td>4.188</td>
<td>4.063</td>
<td>0.170</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>(0.728)</td>
<td>(0.878)</td>
<td>(3.500-4.750)</td>
<td>(3.188-4.438)</td>
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*Statistic could not be presented because participants from this group were unable to play the OTS board and the measure value could not be logically assumed to be zero.

**DISCUSSION**

Making AVGs accessible to people with disabilities offers an innovative approach to overcoming a number of barriers to participation in physical activity. To date, AVG controllers have not been designed in a way to promote active play in persons who require a wheelchair for mobility. Although several studies have documented increases in energy expenditure during AVG by individuals with mobility impairments who played standing [30,31,35,36], limited evidence is available regarding outcomes associated with AVG play while seated. A feasibility study conducted by Rowland and Rimmer [12], modified the parameters for Dance, Dance Revolution game play to allow for arm use by putting the mat on a table and found increases in energy expenditure among three nonambulatory young adults with CP. Recognizing the potential for AVG play to increase energy expenditure among those with more severe mobility impairments led our team to develop an adapted balance board gaming controller [44]. Following from this, the objective of the current study was to examine energy expenditure and enjoyment during active video gaming in persons with mobility impairments utilizing both OTS and adapted versions of the Wii Fit balance board.

Resting METs were compared to gameplay METs for each subgroup (based on degree of mobility impairment) to determine if players actually experienced an increase in energy expenditure during AVG play above resting values. Given the severity of mobility impairment of some participants this could not be assumed. The significant differences between gameplay and resting MET values for all players suggests that AVG play using the adapted controller may provide a leisure-time physical activity option that reduces sedentary time for individuals with a variety of mobility limitations. The increased usability of the gaming board opens the door to AVG play for many who were previously unable to play [10,44].

Seated players were unable to utilize the OTS board therefore measuring change in METs from rest to game play equaled to zero (ie, METs remained at resting values). However, on the adapted board participants who played seated were able to achieve average MET values of 2.261 (0.718) and 2.233 (0.751) kcal/kg/hour on the two game sets respectively. Average MET values for those who played standing were a bit higher (2.887 (0.823); 2.881 (0.898) kcal/kg/hour) as would be expected given the ability to engage greater muscle mass (ie, lower extremity). Although these average values represent light intensity exercise, 16% of seated participants and 41% of standing participants achieved moderate intensity exercise on at least one of the games. These standard categories based on MET values, however, do not take into account the effect of an individual's impairment level on intensity of exercise.
In some cases, self-reported rating of perceived exertion (RPE) on a 0-10 scale suggested greater exercise intensity levels than MET levels recorded. Seated players reported a median RPE of 4 (moderate) for both game sets. Players who could only play standing on the adapted board reported somewhat hard to moderately hard RPE levels (5-6), while players who played standing on both boards reported moderate to somewhat hard RPE levels (4-5).

In a study on healthy young adults, in which participants played various Wii games, exercise intensity varied by game ranging from light to moderate [24]. The authors suggest that for games that require controller skill exercise intensity may be influenced by the player’s prior gaming experience. Furthermore, the benefits of light intensity exercise are acknowledged even if moderate levels are not reached, as was the case for some participants in the current study. As noted in a recent study published in the Journal of the American Heart Association, replacing sedentary time with light intensity physical activity is associated with less mortality in the general population of adults ≥40 years of age [49], with beneficial effects on health outcomes such as blood glucose [50].

In addition to the potential for increased energy expenditure, many also perceive AVGs as fun, providing an enjoyable option by which to accumulate recommended daily amounts of physical activity. In the current study, PACES scores indicated that all players, seated and standing, enjoyed playing each of the game sets, with median scores of 4 on a 5-point scale. In a study comparing heavy-bag boxing to AVG boxing in a seated position among persons with spinal cord injury, participants reported more enjoyment during the AVG boxing [38]. In another study, gameplay performance and exercise intensity were positively correlated with AVG enjoyment in youth with mobility impairments [51]. Enjoyment may serve as a determinant of physical activity suggesting the need to develop AVG interventions and examine the role of enjoyment on level of engagement, exercise intensity, and adherence.

**Limitations**

This study was not a randomized controlled trial; therefore, no claims can be made regarding causality or efficacy. As an observational study inherent limitations existed and thereby limit generalizable of results to the broader community. All participants were recruited from the membership of a community physical activity and recreation center for individuals with physical disabilities. Individuals were to some degree physically active with varied AVG experience. Factors not accounted for that may have influenced intensity of exercise include: 1) game selection, 2) limited familiarization period, and 3) discomfort wearing the COSMED system for oxygen consumption measurement. Although a familiarization period was provided, some degree of gameplay learning may have been occurring during data collection. In addition, participants played only a select group of AVGs. Therefore, potential differences in enjoyment and energy expenditure between OTS and adapted controllers may not have been fully captured. Furthermore, the standard categories of exercise intensity based on MET values do not take into consideration the effect of impairment level on exercise intensity. Furthermore, the intrinsic nature of measures examining subjective aspects of exercise such as enjoyment and perceived exertion prevented these aspects from being compared across board type for the
participants, who were unable to utilize the OTS board. Future studies should expand the participant recruitment pool, examine a broader range of AVGs, provide a more extensive familiarization period, and compare AVG play utilizing the adapted controllers to other leisure-time physical activities.

Conclusions
The adapted board improved access and allowed participants of all mobility levels to engage in AVG play, removing barriers associated with the OTS board. The adapted game controller provided AVG gameplay options for individuals unable to stand during play. Players were able to achieve MET values above resting thereby reducing sedentary time. Furthermore, light to moderate intensity exercise levels were reached by some participants providing an enjoyable option for engagement in health-related physical activity.

ACKNOWLEDGEMENTS
The contents of this article were developed under a RERC RecTech grant from the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR grant numbers 90RE5009-01-00 and 90REGE0002-01-00). NIDILRR is a Center within the Administration for Community Living (ACL), Department of Health and Human Services (HHS). The contents of this article do not necessarily represent the policy of NIDILRR, ACL, HHS, and you should not assume endorsement by the Federal Government. Thanks to Justin McCroskey, Brandon Kane, and Lieu Thompson for their assistance with this project as part of the research team.

CONFLICTS OF INTEREST
None declared.

ABBREVIATIONS
ACSM: American College of Sports Medicine
aSit: participants were seated for gameplay
aStd: participants were able to stand, but due to mobility and/or balance issues could not access the OTS board, therefore played only on the adapted board
AVG: active video game
CP: cerebral palsy
ICF: International Classification of Functioning, Disability and Health
IQR: interquartile range
METs: metabolic equivalent
OTS: off-the-shelf
PACES: Physical Activity Enjoyment Scale
PROMIS: Patient Reported Outcomes Measurement Information System
RERC RecTech: Rehabilitation Engineering Research Center on Interactive Exercise Technologies and Exercise Physiology for People with Disabilities
RPE: rating of perceived exertion
SCI: spinal cord injury
SD: standard deviation
StdStd: participants were able to stand for gameplay on both boards
SUS: System Usability Scale
UAB: University of Alabama at Birmingham
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