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## The Physiological Cost and Enjoyment of Wii Fit in Adolescents, Young Adults, and Older Adults

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**Background:** Active video games (exergames) increase energy expenditure (EE) and physical activity (PA) compared with sedentary video gaming. The physiological cost and enjoyment of exergaming in adolescents, and young and older adults has not been documented, nor compared with aerobic exercise. This study compared the physiological cost and enjoyment of exergaming on Wii Fit with aerobic exercise in 3 populations. **Methods:** Cardiorespiratory and enjoyment measurements were compared in 14 adolescents, 15 young adults, and 13 older adults during handheld inactive video gaming, Wii Fit activities (yoga, muscle conditioning, balance, aerobics), and brisk treadmill walking and jogging. **Results:** For all groups EE and heart rate (HR) of Wii Fit activities were greater than handheld gaming ( $P < .001$ ) but lower than treadmill exercise ( $P \leq .001$ ). Wii aerobics elicited moderate intensity activity in adolescents, young adults, and older adults with respective mean (SD) metabolic equivalents of 3.2 (0.7), 3.6 (0.8), and 3.2 (0.8). HR during Wii aerobics fell below the recommended intensity for maintaining cardiorespiratory fitness. Group enjoyment rating was greater for Wii balance and aerobics compared with treadmill walking and jogging ( $P \leq .05$ ). **Conclusions:** Wii Fit appears an enjoyable exergame for adolescents and adults, stimulating light-to-moderate intensity activity through the modification of typically sedentary leisure behavior.

**Keywords:** physical activity, video games, energy expenditure, sedentary behavior

There is increasing concern that children and adults are insufficiently active to benefit health,<sup>1,2</sup> with motorized transport, safety concerns, fewer manual jobs and sedentary leisure activities espoused as contributing factors.<sup>3,4</sup> With sedentary behavior being described as a modifiable risk factor for lifestyle related diseases,<sup>5</sup> the development of active video games (exergames) that stimulate greater activity during gaming through upper limb or total body movement<sup>6</sup> may help to encourage physical activity (PA) during typically sedentary behaviors.

Cross-sectional research indicates that exergames such as Wii Sports, dance simulators, and those used with the EyeToy and XaviX gaming systems significantly increase energy expenditure (EE) and PA compared with sedentary video games in children and adolescents.<sup>6-11</sup> However, these games have focused on a small range of activities and sports, with research generally limited to youth age 6 to 16 years. Recently, an interactive fitness game (Wii Fit, Nintendo Wii, Nintendo Co Ltd, Minamiku Kyoto, Japan) was launched to engage people of all ages in a range of home-based exercises. While Wii Fit may provide alternative opportunities for PA in the home,

it is important to assess the physiological cost of this new form of exergaming and contextualize findings in relation to PA guidelines that are recommended for health benefits. Current guidelines for children and adults are to accumulate at least 60 and 30 minutes of at least moderate intensity PA each day,<sup>3,12</sup> respectively, with evidence of light-to-moderate intensity activity providing health benefits in older adults.<sup>12</sup>

Enjoyment of an activity in children and adults is a key determinant influencing the allocation of one's time to that pursuit.<sup>13,14</sup> Specifically, if people enjoy exergaming, sustained participation in this behavior over a prolonged period may ultimately benefit PA engagement and accrual. Research suggests that children and adolescents enjoy interacting with screen based media.<sup>15,16</sup> Furthermore, when given the opportunity to participate in active or inactive forms of screen-based media, children are reportedly more motivated to select the active alternative in a laboratory and home setting due to its interactive nature.<sup>17,18</sup> However, no research to date has reported the enjoyment levels of exergaming on Wii Fit across any age groups. Such information could inform future interventions that use exergaming protocols.

The purpose of this study therefore was to evaluate the physiological cost and enjoyment of adolescents, and young and older adults while playing Wii Fit, compared to sedentary video gaming, brisk treadmill walking,

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and jogging. Specific objectives were to compare EE, heart rate (HR), and enjoyment between handheld inactive video gaming and Wii Fit activities (yoga, muscle conditioning, balance, aerobics), and Wii aerobics, brisk treadmill walking, and jogging.

## Method

Fourteen adolescents (11–17 years; 4 female, 10 male), 15 young adults (21–38 years; 8 female, 7 male), and 13 older adults (45–70 years; 3 female, 10 male) visited the laboratories on 2 occasions to complete a familiarization session and experimental trial. Data collection occurred between April and May 2008. Participants were recruited via word of mouth and had no previous experience of Wii Fit. Participants, and when applicable their parents, gave written informed consent and assent respectively, and the study was approved by the University ethics committee.

### Familiarization

Stature was measured to the nearest 0.1 cm using a stadiometer and body mass to the nearest 0.1 kg using a calibrated mechanical scale.<sup>19</sup> Following 2 hours fasting, resting energy expenditure (REE) and resting heart rate (RHR) were measured for 15 minutes with participants in the supine position, using the MetaMax 3B cardiorespiratory system (Cortex, Biophysik, Leipzig, Germany). REE and RHR were obtained by averaging the 9 minutes of data taken from minutes 5 to 14 of the measurement period. Participants then practiced playing the handheld game, Wii Fit, and treadmill walking and jogging.

For handheld inactive video gaming, participants played for 5 minutes on the game Tetris (GameBoy, Nintendo Co Ltd, Minami-ku Kyoto, Japan). Tetris is an externally-paced, falling-blocks puzzle video game, where players join different shapes to make horizontal lines via the use of the D pad and A and B buttons on the console. The game finishes when the screen is full of shapes and lines cannot be completed. Wii Fit familiarization involved participants completing 3 exercises in each of the 4 training categories in the Trial mode. The exercises completed are described in the Appendix. All exercises, except jogging, required interaction with the Wii Balance Board (dimensions 34.3 × 52.1 × 8.1 cm) placed on the floor 3 m from a screen. The wireless Board is a video game controller containing sensors that measure the gamers' center of pressure when stood on. Without shoes, participants were directed to follow on screen instructions and perform each exercise in a comfortable manner. Participants were provided with assistance if required, to help maintain balance. For motorized treadmill familiarization, participants were asked to 'walk briskly' and 'jog' at a self-selected speed for 5 minutes each. Following activity familiarization participants were introduced to the items they would respond to on the modified Physical Activity Enjoyment Scale (PACES)<sup>20</sup> and encouraged to raise any questions or concerns.

### Experimental trial

Participants were fitted with the MetaMax 3B and performed each of the following 7 activities for 10 minutes, in the order listed, interspersed with 5 minutes seated rest: handheld inactive video gaming, Wii yoga, Wii muscle conditioning, Wii balance, Wii aerobics, treadmill walking, treadmill jogging. This order was perceived to represent a progressive increase in exercise intensity. Following each activity, participants completed the modified PACES.

For handheld inactive video gaming on Tetris, participants played on the single player mode starting at the easiest level. Once a game finished the activity was restarted and this continued throughout the 10 minutes. For each Wii Fit activity, participants performed the 3 exercises practiced during familiarization in the order stated (see Appendix). Once the 3 exercises were completed the participant restarted the sequence and continued this for the 10 minutes. Though directed to follow onscreen instructions a range of movements were observed, including actions similar to those requested and modified movements that allowed participants to perform exercises within their physical limits. Several older adults marched on the spot for jogging. For brisk treadmill walking and jogging, participants exercised at the self-selected speeds determined at familiarization.

### Instruments

**MetaMax 3B.** The portable MetaMax 3B measured breath-by-breath oxygen consumption ( $\text{VO}_2$ ) and HR throughout the trial by indirect calorimetry and ECG monitoring, respectively, which were recorded using MetaMax software (Statera Edition, Version 3). The system allows unrestricted movement during physical activities for children and adults, has been used in similar studies,<sup>6,9</sup> and is valid and precise.<sup>21,22</sup> Participants breathed into an appropriately sized facemask covering the nose and mouth, with 5 leads for ECG monitoring attached to participants via ECG electrodes (52 × 54-mm; AgCl, Red Dot 2570, 3M). In accordance with recommendations gas sensors were calibrated against known concentrations, respiratory volume was calibrated using a 3 l syringe, and repeated ambient air measurements were conducted before each trial. Throughout resting and trial periods  $\text{VO}_2$  and HR data were averaged over 15-second epochs.

**Physical Activity Enjoyment Scale (PACES).** A modified PACES<sup>20</sup> determined enjoyment while undertaking the activities, with 5 items from the original 18 items being included in the study (see Appendix). Items were chosen to reflect the study aims. Individuals rated the extent to which they agreed with each item on a 7-point Likert-type scale. For each activity, for each participant, total responses were summed to give a score ranging from 5 to 35, and a percentage enjoyment score was calculated. The PACES has been found to have both reliability and validity in PA environments.<sup>20</sup> Reliability

of the 5 items were high for each activity using pooled data from the 3 age groups (Cronbach's alphas  $\geq 0.742$ ), and data from each age subgroup (adolescents  $\geq 0.739$ , young adults  $\geq 0.783$ , older adults  $\geq 0.840$ ).

## Statistical Analysis

Oxygen uptake (l/min) and HR (beats/min) data were averaged for the 10 minutes of each activity. Energy expenditure (J/kg/min) was derived from  $\text{VO}_2$  using established constants (1 l  $\text{O}_2 = 4.9$  kcal; 1 kcal = 4.18 kJ).<sup>23</sup> Metabolic equivalents (METs) for each participant, for each activity, were derived by dividing the average  $\text{VO}_2$  of the activity by the participants' average resting  $\text{VO}_2$ . Results are expressed as means and standard deviations. Differences between groups for descriptives and treadmill speeds were analyzed using one-way analysis of variance (ANOVA).

Mixed-design ANOVAs were run on the variables  $\text{VO}_2$ , EE, HR, and enjoyment. First, a three-group mixed ANOVA was performed with *age group* (adolescents, young adults, older adults) as the between-subjects factor and *activity* (handheld gaming, Wii yoga, Wii muscle conditioning, Wii balance, Wii aerobics, brisk treadmill walking) as the within-subjects factor.<sup>24</sup> Secondly, to run comparisons including jogging data, older adults were excluded due to low compliance, and a two-group mixed ANOVA was performed with factors of age group (adolescents, young adults) and activity (handheld gaming, Wii yoga, Wii muscle conditioning, Wii balance, Wii aerobics, brisk treadmill walking, treadmill jogging).<sup>24</sup> In the presence of a significant main effect for activity or age group, post hoc pairwise comparisons were investigated. Vertical multiple comparisons among pairwise group means were performed with a Bonferroni correction for type I error control when the activity  $\times$  age group interaction was significant.<sup>25</sup> Vertical comparisons for the two- and three-group mixed ANOVA were conducted using independent *t* tests and one-way between subjects ANOVA, respectively. Post hoc analysis for the one-

way ANOVA revealed where any significant differences lay between groups. In the incidence of missing data, participants were only removed from any analysis that included the dependent variable missing. SPSS, v14 was used for statistical analysis with statistical significance set at  $P \leq .05$ .

## Results

Anthropometric characteristics of the sample are described in Table 1. All participants completed all activities, except 10 older adults (7 male, 3 female) who did not jog on the treadmill due to physical limitations. HR data were lost for 1 participant (female young adult) during treadmill walking due to monitoring problems.

### $\text{VO}_2$ , EE, and HR

The three-group mixed ANOVA resulted in a significant main effect for activity for  $\text{VO}_2$ , EE, and HR ( $F = 243.55$ ,  $324.26$ , and  $129.78$ , respectively,  $P < .001$ ), as did the two-group mixed ANOVA ( $\text{VO}_2$ :  $F = 545.73$ ; EE:  $F = 774.45$ ; HR:  $F = 345.12$ ,  $P < .001$ ) (Tables 2, 3, 4).  $\text{VO}_2$ , EE, and HR for Wii Fit sessions were greater than handheld gaming ( $P < .001$ ) and lower than treadmill walking and jogging ( $P \leq .001$ ). An age group main effect for EE was found on the three-group mixed ANOVA ( $F = 9.47$ ,  $P < .001$ ), with older adults having significantly lower EE compared with adolescents and young adults ( $P \leq .002$ ). There were no main effects for age group for the two-group analysis ( $P > .05$ ). The three-group mixed ANOVA resulted in a significant activity  $\times$  age group interaction for EE ( $F = 5.08$ ,  $P < .001$ ). One-way ANOVA indicated significant differences between groups for handheld gaming, Wii muscle conditioning, Wii aerobics, and treadmill walking ( $P_{\text{corrected}} \leq 0.024$ ), with post hoc tests indicating older adults had lower EE than adolescents and young adults ( $P \leq 0.039$ ). The two-group analysis resulted in a significant activity  $\times$  age group interaction for  $\text{VO}_2$  ( $F = 3.27$ ,  $P = .041$ ) and EE

**Table 1 Mean (SD) Descriptive Characteristics and Self-Selected Treadmill Speeds**

	Adolescents (n = 14)	Young adults (n = 15)	Older adults (n = 13)
Age (years)	15.8 (1.3)	28.2 (4.6) <sup>a</sup>	57.6 (6.7)
Stature (m)	1.70 (0.12)	1.71 (0.10)	1.69 (0.07)
Mass (kg)	66.2 (11.3)	65.9 (8.7)	81.5 (13.5) <sup>b</sup>
BMI (kg/m <sup>2</sup> )	22.8 (3.3)	22.6 (1.3)	28.4 (4.4) <sup>b</sup>
Brisk treadmill walking speed (km/h)	5.3 (0.9)	6.1 (0.6) <sup>a</sup>	4.8 (1.0)
Treadmill jogging speed (km/h)	8.4 (1.1)	9.7 (0.8) <sup>a</sup>	7.7 (0.6) <sup>c</sup>

<sup>a</sup>  $P \leq 0.028$  different from adolescents and older adults (one-way ANOVA).

<sup>b</sup>  $P \leq .003$  different from adolescents and young adults (one-way ANOVA).

<sup>c</sup> n = 3, descriptor provided for reference.

( $F = 4.22$ ,  $P = .01$ ), though independent  $t$  tests indicated no differences in these variables between groups for any activity ( $P_{corrected} \geq 0.41$ ).

Based on established boundaries for PA intensity classification (Light < 3, Moderate 3–6, Vigorous > 6

METs)<sup>3,12</sup> all activities were classified as light except Wii aerobics and brisk treadmill walking (moderate), and treadmill jogging (vigorous), for all groups (Table 5). Using a maximum HR ( $HR_{max}$ ) of 200 beats/min for adolescents of this age,<sup>26</sup> the intensity of Wii aerobics cor-

**Table 2 Mean (SD) Oxygen Consumption ( $VO_2$ ) for Each Activity**

Activity	$VO_2$ (l/min)		
	Adolescents	Young adults	Older adults
Rest	0.35 (0.07) <sup>a</sup>	0.31 (0.05) <sup>a</sup>	0.32 (0.07) <sup>a</sup>
Handheld gaming	0.36 (0.09) <sup>a</sup>	0.34 (0.06) <sup>a</sup>	0.32 (0.07) <sup>a</sup>
Wii yoga	0.60 (0.10)	0.57 (0.14)	0.57 (0.16)
Wii muscle conditioning	0.74 (0.12)	0.73 (0.17)	0.68 (0.22)
Wii balance	0.59 (0.11)	0.58 (0.13)	0.57 (0.17)
Wii aerobics	1.09 (0.17)	1.09 (0.22)	0.96 (0.29)
Brisk treadmill walking	1.20 (0.26) <sup>a</sup>	1.35 (0.26) <sup>a</sup>	1.17 (0.47) <sup>a</sup>
Treadmill jogging	2.21 (0.43) <sup>a</sup>	2.44 (0.35) <sup>a</sup>	

<sup>a</sup>  $P \leq .001$  different from Wii Fit activities (three- and two-group mixed ANOVA).

**Table 3 Mean (SD) Energy Expenditure (EE) for Each Activity**

Activity	EE (J/kg/min)		
	Adolescents	Young adults	Older adults
Rest	111.7 (22.7) <sup>a</sup>	96.9 (12.8) <sup>a</sup>	78.4 (14.2) <sup>a</sup>
Handheld gaming	113.5 (26.3) <sup>a</sup>	109.0 (13.7) <sup>a</sup>	84.1 (20.0) <sup>a,b</sup>
Wii yoga	190.8 (34.6)	178.8 (33.4)	148.7 (40.9)
Wii muscle conditioning	236.8 (36.4)	230.2 (39.2)	178.7 (61.1) <sup>b</sup>
Wii balance	188.2 (31.0)	182.8 (39.0)	150.8 (50.1)
Wii aerobics	348.1 (44.7)	345.3 (59.6)	252.2 (83.6) <sup>b</sup>
Brisk treadmill walking	384.9 (81.1) <sup>a</sup>	429.7 (57.7) <sup>a</sup>	302.7 (103.7) <sup>a,b</sup>
Treadmill jogging	697.7 (89.9) <sup>a</sup>	764.7 (89.4) <sup>a</sup>	

<sup>a</sup>  $P \leq 0.001$  different from Wii Fit activities (three- and two-group mixed ANOVA).

<sup>b</sup>  $P \leq .039$  different from adolescents and young adults (three-group mixed ANOVA).

**Table 4 Mean (SD) Heart Rate (HR) for Each Activity**

Activity	HR (beats/min)		
	Adolescents	Young adults	Older adults
Rest	67.9 (12.7) <sup>a</sup>	58.3 (8.2) <sup>a</sup>	68.0 (12.3) <sup>a</sup>
Handheld gaming	70.9 (13.1) <sup>a</sup>	65.6 (8.7) <sup>a</sup>	74.0 (9.7) <sup>a</sup>
Wii yoga	86.6 (16.2)	77.6 (10.5)	83.8 (9.5)
Wii muscle conditioning	90.2 (15.3)	82.4 (11.9)	86.8 (10.2)
Wii balance	85.0 (15.6)	76.7 (10.9)	84.5 (9.9)
Wii aerobics	101.9 (18.4)	94.5 (10.1)	94.7 (11.2)
Brisk treadmill walking	111.8 (17.5) <sup>a</sup>	108.3 (11.4) <sup>a</sup>	102.5 (15.0) <sup>a</sup>
Treadmill jogging	154.9 (19.4) <sup>a</sup>	153.7 (12.0) <sup>a</sup>	

<sup>a</sup>  $P \leq .001$  different from Wii Fit activities (three- and two-group mixed ANOVA).

responded to 51%  $HR_{max}$  compared to 56% for treadmill walking and 77% for treadmill jogging. For young and older adults, with  $HR_{max}$  estimated using the equation:  $HR_{max} = 205.8 - (0.685 \times \text{age})$ ,<sup>27</sup> respective intensities elicited were 51% and 57%  $HR_{max}$  for Wii aerobics, 58% and 62% for treadmill walking, and 82% for treadmill jogging in young adults.

## Enjoyment

The three- and two-group mixed ANOVA resulted in a significant main effect for activity for enjoyment (respective  $F = 13.46$  and  $16.20$ ,  $P < .001$ ) (Table 6). The three-group analysis indicated enjoyment for all Wii Fit sessions was greater than handheld gaming ( $P \leq .003$ ), except Wii yoga ( $P > .05$ ), and greater for Wii balance and Wii aerobics compared with treadmill walking ( $P \leq$

$0.05$ ). The two-group analysis indicated enjoyment for Wii Fit sessions was greater than handheld gaming ( $P \leq .029$ ), greater than treadmill walking for Wii muscle conditioning, Wii balance and Wii aerobics ( $P \leq .031$ ), and greater than treadmill jogging for Wii balance and Wii aerobics ( $P \leq .035$ ). There were no main effects for age group for either ANOVA ( $P \geq 0.390$ ). The three-group analysis resulted in a significant activity  $\times$  age group interaction ( $F = 2.73$ ,  $P = .011$ ). One-way ANOVA indicated differences between groups for treadmill walking ( $P_{corrected} = 0.028$ ), with post hoc tests indicating older adults had higher enjoyment than adolescents and young adults ( $P \leq 0.023$ ). Though the two-group analysis resulted in a significant activity  $\times$  age group interaction for enjoyment ( $F = 3.71$ ,  $P = .005$ ), independent  $t$  tests indicated no differences between adolescents and young adults ( $P_{corrected} \geq 0.196$ ).

**Table 5 Mean (SD) Metabolic Equivalent (METs) for Each Activity**

Activity	METS		
	Adolescents	Young adults	Older adults
Handheld gaming	1.0 (0.1)	1.1 (0.1)	1.1 (0.3)
Wii yoga	1.7 (0.3)	1.9 (0.4)	1.9 (0.4)
Wii muscle conditioning	2.2 (0.4)	2.4 (0.4)	2.3 (0.6)
Wii balance	1.7 (0.4)	1.9 (0.5)	1.9 (0.5)
Wii aerobics	3.2 (0.7)	3.6 (0.8)	3.2 (0.8)
Brisk treadmill walking	3.5 (0.5)	4.5 (1.0)	4.0 (1.5)
Treadmill jogging	6.5 (1.5)	8.0 (1.2)	

**Table 6 Mean (SD) physical activity enjoyment scale (PACES) percentage score for each activity**

Activity	Enjoyment (%)		
	Adolescents	Young adults	Older adults
Handheld gaming	60.8 (18.8) <sup>a,c</sup>	62.1 (11.0) <sup>a,c</sup>	72.3 (22.1) <sup>a</sup>
Wii yoga	78.6 (15.0)	67.0 (12.4)	70.3 (25.0)
Wii muscle conditioning	77.8 (16.9)	74.7 (13.0)	80.0 (18.4)
Wii balance	84.3 (15.1)	80.8 (12.1)	85.5 (14.2)
Wii aerobics	90.4 (9.8)	85.3 (13.6)	80.4 (15.4)
Brisk treadmill walking	65.5 (17.1) <sup>b,d</sup>	69.3 (14.9) <sup>b,d</sup>	86.2 (10.4) <sup>b,f</sup>
Treadmill jogging	59.8 (24.8) <sup>e</sup>	77.3 (13.3) <sup>e</sup>	

<sup>a</sup>  $P \leq .003$  different from Wii muscle, Wii balance, Wii aerobics (three-group mixed ANOVA).

<sup>b</sup>  $P \leq .05$  different from Wii balance, Wii aerobics (three-group mixed ANOVA).

<sup>c</sup>  $P \leq .029$  different from Wii Fit activities (two-group mixed ANOVA).

<sup>d</sup>  $P \leq .031$  different from Wii muscle, Wii balance, Wii aerobics (two-group mixed ANOVA).

<sup>e</sup>  $P \leq .035$  different from Wii balance, Wii aerobics (two-group mixed ANOVA).

<sup>f</sup>  $P \leq .023$  different from adolescents and young adults (three-group mixed ANOVA).

## Discussion

The current study compared the physiological cost and enjoyment of adolescents, and young and older adults while playing Wii Fit, a handheld inactive video game, and brisk treadmill walking and jogging. For all participants, EE and HR during yoga, muscle conditioning, balance, and aerobic Wii Fit activities were significantly greater than handheld sedentary gaming, congruent with other exergames.<sup>6-11</sup> In contrast, original results from 3 populations suggest that EE and HR during exergaming on Wii Fit were significantly lower than treadmill walking and jogging, with energy cost disparities likely due to the intermittent nature of exergaming<sup>28</sup> compared with continuous treadmill exercise.

For all age groups the EE of Wii aerobics was of moderate intensity. For young and older adults the energy cost is comparable to activities of trampolining and walking leisurely.<sup>29</sup> In adolescents, Wii aerobics is comparable to other moderately intense exergames including Wii Sports boxing,<sup>6</sup> Homerun, Knockout, and Cascade on the Sony EyeToy,<sup>9,10</sup> Dance UK on the Playstation 2,<sup>9</sup> and Dance Dance Revolution on the XBOX in overweight youth.<sup>8</sup> In contrast, Wii yoga, muscle conditioning and balance activities were of light intensity and comparable to exergames of Wii Sports bowling and tennis,<sup>6,7</sup> Nicktoons Movin', Groove and AntiGrav on the Sony EyeToy,<sup>8,9</sup> and Dance Dance Revolution in lean youth.<sup>8</sup> These findings indicate that vigorous intensity activity has yet to be consistently elicited through exergaming, and, from the current study only time spent participating in the described Wii aerobics activity would contribute to adolescent and adult recommendations for health benefiting PA.<sup>3,12</sup> However, for older adults, activity recommendations<sup>12</sup> would suggest that participation in the light-to-moderately intense Wii Fit activities may help reduce their risk for all cause-mortality, cardiovascular disease, and type-2 diabetes.<sup>12</sup> Furthermore, encouraging such activity in all populations is arguably positive in that it is modifying traditionally sedentary leisure behavior by changing the way a person interacts with the game, and future research is needed to determine any associated health benefits, both physical and psychological, of sustained exergaming on Wii Fit over time. Interventions using Wii Fit should assess changes in components of fitness targeted by the game, such as muscular strength and endurance, cardiorespiratory fitness, balance, coordination, and flexibility, in addition to habitual physical activity.

To maintain or develop cardiorespiratory fitness, young people are recommended to exercise at an intensity of 80%  $HR_{max}$ <sup>30</sup> while adults should exercise at 60%  $HR_{max}$ .<sup>31</sup> In the current study, only treadmill walking in older adults and treadmill jogging in young adults fulfilled these targets, with the Wii aerobic session in the current study failing to adequately stress the metabolic pathways required for such positive changes. It is important to note however that the exercises available

in the Trial mode are the easiest available and are not representative of all exercises on Wii Fit. Exercises in the main section of the game may be more difficult and elicit higher EE and/or HR; however these are unlocked through sustained participation, hence why the Trial mode was used.

The enjoyment derived from the balance and aerobic Wii Fit activities were comparable if not greater than handheld inactive video gaming and treadmill exercise for all age groups. Enjoyment is an important determinant influencing the time an individual allocates to an activity.<sup>13,14</sup> Furthermore, repetitive activities such as walking can lead to boredom,<sup>32</sup> which is not viewed as an enjoyable state.<sup>33</sup> Therefore, if inactive individuals, who may not adhere to regular aerobic exercise due to a potential lack of enjoyment derived from it, enjoy exergaming similarly to adolescents and adults in the current study, they may be more likely to sustain participation in light-to-moderate intensity exergaming. Marked enjoyment disparities for adolescents between Wii aerobics and treadmill exercise suggest this population may be most receptive to advancing innovative technologies aiming to reduce sedentariness and stimulate PA. This is further supported by young people's intermittent habitual activity patterns matching the intermittent nature of exergaming,<sup>34</sup> and their familiarity with such technology given the proportion of time spent playing sedentary video games.<sup>16</sup>

Interestingly, of the exergaming activities performed, older adults enjoyed Wii balance greatest. Compared primarily to Wii yoga and muscle conditioning, this may be due to balance exercises comprising a motivational game element. Furthermore, some balance exercises were self-paced, allowing participants to dictate how and when they moved rather than conforming to onscreen character actions. For older adults, such a characteristic of an exergame seems beneficial due to their likely movement restrictions compared with younger populations. As such, these exercises may be enjoyable methods that could potentially help improve balance in older adults and minimize age related impairments in balance, which has been shown to increase the risk of falling and fall injuries.<sup>35,36</sup>

Differences in physiological cost between groups were observed in the current study, with older adults' EE lower than adolescents and young adults during handheld inactive video gaming, Wii muscle conditioning, Wii aerobics, and treadmill walking. For the exergames, this is likely attributable to physical limitations in older adults inhibiting their ability to perform the full ranges of motion required. The consequential modified actions that allowed older adults to perform the exercises with less physical discomfort would result in reduced muscle contraction and hence EE. For brisk treadmill walking, EE differences are likely explained by older adults self-selecting the lowest speed of all the age groups.

Limitations of this paper include a small sample for each age group, though this is comparable to similar research studies.<sup>6,7,10,11,28</sup> This was due to multiple population involvement in the study, which provided original

information on the use of exergames in groups other than youth. Participation in the study was voluntary, hence enjoyment responses may be biased compared with individuals who did not volunteer, with caution warranted when generalizing findings beyond this sample. Future research with larger sample sizes and diverse populations are needed to replicate the findings presented. A second limitation was the comparison of exergaming with only treadmill walking and jogging. These activities were selected as a comparative due to their feasibility in the research process and because they represent typical daily activities. Nevertheless enjoyment of treadmill locomotion may differ from over-ground equivalents, so caution is warranted when interpreting these findings. Future investigations may compare the physiological cost and enjoyment of Wii Fit exercises with real-life equivalents, such as yoga and muscle conditioning exercises. A third limitation, common in similar research studies, was the short duration of participation in each activity, which provided information on acute physiological and enjoyment responses. Only through longitudinal studies can researchers determine any associated changes in EE and/or HR with experience, and if enjoyment of Wii Fit is maintained over time or whether one habituates to the once novel games and then stops using them. A fourth limitation was not randomizing the order of activities during the trial. This occurred to allow for the most efficient experimental design, which was necessary due to limited participant availability. An additional limitation was the potential effect of a previous activity on physiological parameters in the subsequent activity. However, the 5-minute seated rest period, which is common for such investigations,<sup>6–9</sup> would likely eliminate any significant effect of the previous activity. The intermittent nature of Wii Fit, inclusive of transient rest periods, would further reduce any potential effects. A sixth limitation was the missing treadmill jogging data for older adults, which resulted in the running of both three- and two-group mixed ANOVA models. However, because of this missing cell such analyses was necessary to test the between and within subjects effects across all conditions. A seventh limitation was the use of a handheld game rather than a console game, such as the PlayStation, for sedentary gaming. This may have altered the relationship between gaming and EE or enjoyment. However, previous research reported little or no differences in EE or HR between sedentary gaming on a handheld game or a gamepad, keyboard or steering wheel with pedals connected to a PlayStation console, suggesting comparable physical effort is required across sedentary video game input devices.<sup>11</sup> Regarding enjoyment, caution must be taken if extrapolating findings to other sedentary video games, with future research exploring such differences and possible effects on sustained gaming warranted. A final limitation was the use of the PACES to determine enjoyment from handheld gaming, as this instrument is specific to PA. However, the instrument was used to maintain consistency in assessment of this variable across

activities and is more comprehensive than using a single item to measure enjoyment.

## Conclusions

The physiological cost of exergaming on Wii Fit was significantly greater than handheld inactive video gaming but lower than treadmill exercise for 3 different age groups (adolescents, young adults, and older adults). PA intensities elicited by Wii aerobics were within daily health-benefiting PA recommendations for all age groups. The acute enjoyment response derived from Wii balance and Wii aerobics was comparable if not greater than handheld inactive gaming and treadmill exercise, especially in adolescents, suggesting individuals may be more likely to adhere to sustained light to moderate intensity exergaming.

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## Appendix

### Description of Wii Fit Exercises

Training category exercise	Description
Yoga	
Half moon	With both arms raised above the head, lean the upper body to the left and right sides and hold the stretch in time with the onscreen instructor.
Warrior	With 1 foot on the Balance Board and the other behind the Board, bend the leading knee and hold the stretch with outstretched arms in time with the onscreen instructor.
Tree	With the bottom of the foot on the inner thigh or calf, extend the arms up and stand straight, in time with the onscreen instructor.
Muscle conditioning	
Single-leg extension	With 1 foot on the Board and the other raised, extend the raised leg back and forth while reaching forward and back with the arm opposite to the raised leg in time with the onscreen instructor.
Trunk and waist twists	With arms outstretched, twist the trunk to the left and right, and, twist forward from the waist to the left and right in time with the onscreen instructor.
Lunge	With 1 foot on the Board and the other behind the Board, lower and raise the body by bending both knees in time with the onscreen instructor.
Balance	
Ski slalom	Lean forward, backward, left and right to guide a character through gates down a course.
Heading	Lean left and right to head footballs and avoid other objects.
Balance bubble	Lean forward, backward, left and right to guide a character down a course, avoiding obstacles down the course.
Aerobics	
Hula hoop	Swing the hips and lean left and right to rotate and collect hoops.
Step aerobics	Step on and off the Board to the back and sides in time with sensory instructions (visual and audio).
Jogging	Jog on the spot (on the floor not Board) at a self-selected speed with the Wii Remote held or placed in the trouser/short pocket.

### PACES items: Please rate how you feel *at the moment* about the physical activity you have been doing

1	2	3	4	5	6	7
* I enjoy it						I hate it
1	2	3	4	5	6	7
I dislike it						I like it
1	2	3	4	5	6	7
It's no fun at all						It's a lot of fun
1	2	3	4	5	6	7
* I feel good physically while doing it						I feel bad physically while doing it
1	2	3	4	5	6	7
I am very frustrated by it						I am not at all frustrated by it

\* Item is reverse scored (ie, 1 = 7, 2 = 6, 3 = 5, 4 = 4, 5 = 3, 6 = 2, 7 = 1).