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# Active video games as a form of exercise and the effect of gaming experience: a preliminary study in healthy young adults☆

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**Abstract**

**Objectives** To examine the energy expenditure and heart rate response while playing active video games, and the effect of gaming experience on energy expenditure.

**Design** Cross-sectional study.

**Participants and interventions** Twenty-eight healthy participants (18 male, age 19 to 27 years) played either Wii Sports Boxing, Tennis and Baseball, or Wii Sports Boxing and Wii Fit Free Jogging.

**Main outcome measures** Percentage maximal heart rate (%HRmax) and metabolic equivalents (METs) were measured during 15 minutes of rest and during each game.

**Results** Mean %HRmax and METs while playing each of the four games were as follows: Wii Fit Free Jogging 71% [standard deviation (SD) 13%], 5.9 (SD 1.8); Wii Sports Boxing 58% (SD 13%), 3.2 (SD 1.1); Wii Sports Baseball 42% (SD 6%), 2.0 (SD 0.5); and Wii Sports Tennis 42% (SD 7%), 2.0 (SD 0.4). Subjects with gaming experience achieved a lower heart rate playing Wii Sports Tennis compared with subjects without gaming experience.

**Conclusions** Wii Sports Boxing, Tennis and Baseball are light-intensity activities, and Wii Fit Free Jogging is a moderate-intensity activity. Experience of gaming may affect the exercise intensity of games requiring controller skill.



*Keywords:* Video games; Energy metabolism; Metabolic equivalent

## Introduction

Physical activity is a major factor in the prevention and treatment of obesity, cardiovascular disease and other morbidities [1]. It is recommended that adults should participate in at least 30 minutes of moderate activity at least 5 days per week [1]. For healthy young adults, moderate-intensity exercise is that which results in an energy expenditure of 4.8 to 7.1 metabolic equivalents (METs), or a maximal heart rate (%HRmax) of 64% to 76% [1]. Examples of moderate activity for young adults include walking for exercise, dancing or mowing the lawn [2].

Activity levels have been shown to decline below recommended levels in early adulthood [3]. Watching television and playing computer and video games are thought to contribute to sedentary behaviour in adults [4]. However, video games appeal to young adults [5] and their use is increasing [6].

With the development of active video games (AVGs), computer gaming has the potential to become a more active pastime [7]. An AVG, or interactive game, is defined as electronic media that allows players to actively interface with the game by physical manipulation of equipment [8]. One such AVG console is the Wii™ (Nintendo Co Ltd., Tokyo, Japan). The Wii is primarily operated through a handheld wireless controller (Wii Remote™). Players simulate movements with this controller, and the on-screen character moves in the same way. This allows players to move freely while controlling characters as they engage in activities such as swinging a racket.

Theoretically, if the exercise intensity reached while playing the Wii is moderate, such participation may contribute to the achievement of physical activity guidelines [1].

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Furthermore, the visual and auditory stimulation from these games may provide augmented feedback which can be an effective addition to exercise therapy [9].

A number of studies have investigated the exercise intensity associated with playing the Wii [5,10–16]. Wii Sports is the most common Wii game as it is provided with the console when purchased. Several simulations can be played on Wii Sports, including baseball, golf and bowling, all which result in energy expenditure of just below 3 METs; these are generally considered to be light-intensity games [13,14,16]. Although studies have consistently shown that Wii Sports Boxing (hereinafter known as 'Boxing') is the most active of the Wii Sports simulations, there is uncertainty about whether or not it can be considered a moderate-intensity activity. Some studies found that Boxing required a higher or comparable energy expenditure to brisk walking [11,12,17], while others [13,14] reported it as a light-intensity activity. Differences in methodologies may explain the variations between studies. The study populations varied from children [14] to adults [16], and some studies used electronic devices to estimate energy expenditure [13] while others used indirect calorimetry [14].

AVGs that require whole body movement are likely to be more metabolically demanding than AVGs that only require upper body movement [19]. Wii Fit$^{TM}$ is a game designed to incorporate lower limb movement. Many Wii Fit games are played using a pressure sensitive platform (Wii Balance Board$^{TM}$). On-screen characters can be controlled by players shifting their body weight while standing on this platform. However, it is not capable of supporting the weight of a human landing on it with momentum, and therefore it is not used to play Wii Fit Jogging. Players' movements for jogging simulations are detected through the Wii Remote, which is placed in the player's pocket while they jog.

There are four choices of jogging simulations on the Wii Fit Plus game. Basic Jogging and Jogging Plus are computer-paced games, 2P Wii Jogging allows two players' on-screen characters to jog through the same virtual landscape simultaneously, and Free Jogging is paced by the player and lasts a set time of either 10 or 20 minutes. Wii Fit Free Jogging is unique among Wii simulations in that it has both the desired qualities of being continuous for a minimum of 10 minutes, and necessitates whole body movement.

To the authors' knowledge, three studies have examined the energy expenditure associated with playing Wii Fit games [5,10,16], but none of them used Wii Fit Free Jogging. Miyachi *et al*. reported energy expenditure of 5.1 METs and 4.0 METs during Wii Fit Plus Basic Jogging and Jogging Plus, respectively, in healthy adults aged 25 to 44 years [16]. As such, these games were considered to be moderate-intensity activities in this population [16]. These jogging games were paced by a computer-generated guide.

Graves *et al.* [5] and Guderian *et al.* [10] examined the energy expenditure associated with playing Wii Fit games; however, they grouped different simulations together and did not report the energy expenditure for individual simulations. The combined mean energy expenditure for playing six Wii Fit games among middle-aged and older adults was 3.5 METs [10]. Similarly, the combined mean energy expenditure for playing Wii Fit Hula Hoop, step aerobics and jogging games among young adults was 3.6 METs [5]. Another limitation of these studies was that the trial versions of the games were used, which are shorter and require a lower level of skill than the full versions.

It is not clear whether gaming experience is related to energy expenditure when playing AVGs. Sell *et al.* found that players with gaming experience expended more energy when playing AVGs compared with those without gaming experience [18]. However, some researchers believe that experienced players may adapt their movement patterns while playing to conserve energy [19].

Video games can be played at different levels, either by selection or progress. A methodological difficulty arises when comparing energy expenditure across computer game levels, as these levels can lead to the playing experience being inherently different. A game that is paced by the player from the beginning is therefore preferable when comparing experienced gamers with inexperienced gamers. Research has shown that when children had the opportunity to modify the intensity of an AVG, they accrued more physical activity [8]. No studies examining the exercise intensity reached by adults playing the Wii have investigated the possible effect of gaming experience on energy expenditure.

This study aimed to examine the energy expenditure and heart rate response while playing four Wii simulations, and to compare these results with moderate-intensity exercise guidelines [1]. In addition, the effect of gaming experience on energy expenditure while playing AVGs of different energy requirements was examined.

## Methods

### *Recruitment and design*

Twenty-eight young non-smoking adults (mean age 22 years, 18 male) were recruited through posters on university notice boards. Those with a history of cardiac or respiratory disease, musculoskeletal injury, low back pain in the previous 3 months, taking prescribed medication other than the oral contraceptive pill, and pregnant women were excluded from participation. All testing took place in the exercise laboratory of the Trinity Centre for Health Sciences, Dublin. Written informed consent was received from all participants.

Participants were divided into a Wii Sports group ($n = 12$) and a Wii Fit group ($n = 16$). All Wii Sports simulations were played at the most basic level. Participants in both groups played Boxing. Those in the Wii Sports group also played Wii Sports Baseball and Wii Sports Tennis (hereinafter referred to as 'Baseball' and 'Tennis'). Those in the Wii Fit group also played self-paced Wii Fit Free Jogging (hereinafter referred to as 'Jogging').

*Protocol*

On arrival at the laboratory, participants, who had fasted for 3 hours, completed a physical activity readiness questionnaire [20]. Height was measured with a Seca stadiometer to the nearest 1 cm (Seca Mod 220, Hamburg, Germany). Weight (shoes removed) was measured with a Seca balance beam scale to the nearest 0.1 kg (Seca Mod 220, Hamburg, Germany). The familiarisation period included a demonstration of Wii use, but the participants were not permitted to play the games as this could have affected their subsequent performance. Participants were fitted with a face mask, which was attached to the Oxycon Mobile (Jaeger, Viasys Healthcare, Hoechberg, Germany), and a Polar heart rate monitor (Polar FS1 fitness, Kempele, Finland). The Oxycon Mobile is a valid and reliable [21] lightweight portable indirect calorimeter. Oxygen consumption ($VO_2$), energy expenditure and HR were measured during supine rest and while playing AVGs. The game order was randomised. Each game was played for 15 minutes with a 5-minute seated rest between games. A duration of 15 minutes was chosen to allow energy expenditure to reach a steady state.

Little research has been undertaken on the time required to become skilled at playing computer games requiring movement and coordination. Research has shown that 30 minutes of computer simulation practice improves the performance of participants performing simulated surgery [22]. Therefore, participants were considered to be experienced gamers if they had previously played all the Wii simulations in this study, or had played any of these simulations for an accumulated time exceeding 30 minutes.

*Details on AVGs*

Tennis is a doubles game. Participants have no control over where their on-screen characters move on court, controlling only when and how characters swing their rackets. Baseball involves a team of virtual players that compete in a three-innings game against a computer-controlled team. Players control batting and pitching, but do not control outfielders, infielders or runners, who run automatically. Boxing consists of three 1-minute rounds, unless an on-screen character is knocked out. Players control their characters' punches by simulating punching movements while holding the Wii Remote in their hand. In all Wii Sports simulations, the duration varies depending on the player's ability to score points. Participants were asked to choose to play again after each game until they had played for a total of 15 minutes.

Jogging involves jogging on the spot. The player's movements are detected by the console through the Wii Remote which, to standardise its position, was kept in a small backpack worn by participants. When small quick steps are taken, the on-screen character falls over; therefore, participants were instructed not to shuffle their feet.

Table 1
Participants' characteristics.

| Group | Wii Sports, $n = 12$, 8 male | Wii Fit, $n = 16$, 10 male |
|---|---|---|
| Age (years) | 23 (1) | 22 (3) |
| Height (cm) | 178 (8) | 180 (6) |
| Weight (kg) | 73.0 (7.0) | 75.1 (10.8) |
| Body mass index (kg/m$^2$) | 23.2 (1.8) | 23.1 (2.8) |
| Experienced gamers | 5, all male | 5, all male |

Data presented as mean (standard deviation).

*Statistical analysis*

METs were calculated as gaming $VO_2$ divided by resting $VO_2$. $VO_2$ and HR were averaged over minutes 9 to 14 for each condition. Energy expenditure in joules was summed for the entire 15 minutes of each condition. Participants' age-related predicted maximal HR was calculated as $208 - (0.7 \times \text{age})$ [23]. Single sample *t*-tests were conducted to investigate whether energy expenditure and maximum HR differed significantly from recommendations for moderate activity [1]. Differences between groups, sexes and level of gaming experience within groups were assessed using repeated measures analysis of variance and independent *t*-tests. Data were checked for normality using the Kolmogorov–Smirnov test. JMP Version 7.0.1 (SAS Institute Inc. North Carolina, USA) was used to analyse the results.

For a power of 0.95 with alpha set at 0.05, an a priori power calculation revealed that eight participants were needed in each group to adequately compare the METs expended during Boxing with the minimal accepted requirement for moderate activity (4.8 METs). To detect differences in $VO_2$ between experienced and inexperienced gamers, at least five participants with experience and five participants without experience were required in each group. Power calculations were performed using G*Power Version 3.1.2 (Kiel, Germany).

## Results

There were no significant differences in anthropometric variables between sexes, groups and level of gaming experience. Data were therefore pooled for sex and gaming experience (Table 1). Five participants in each group (all male) were considered to be experienced gamers.

Data were normally distributed, with the exception of kilojoules expended when playing Baseball and Tennis. A common outlier was found for these variables. Laboratory notes recorded during testing reported that the participant in question felt 'uncomfortable and claustrophobic' wearing the face mask. Data pertaining to this outlier were excluded in all subsequent analyses. As there were no significant differences in cardiovascular responses to rest or Boxing between groups, combined data are presented for these conditions (Table 2).

Table 2
Cardiovascular response to rest and active video game play.

| Condition (group) | Heart rate (beats/minute) | %HRmax | Oxygen consumption (ml/minute kg) | Energy expenditure (kJ/15 minutes) | *n* |
|---|---|---|---|---|---|
| Rest (both) | 59.9 (10.9) | n/a | 4.3 (0.9) | 94.7 (19.1) | 27 |
| Boxing (both) | 112.4 (24.4) | 58 (13) | 13.5 (4.1) | 305.5 (96.5) | 27 |
| Tennis (Wii Sports) | 79.9 (12.8)[a] | 42 (7)[a] | 7.7 (1.6) | 171.9 (27.3) | 11 |
| Baseball (Wii Sports) | 80.4 (11.3) | 42 (6) | 8.0 (2.4) | 179.0 (50.5) | 11 |
| Jogging (Wii Fit) | 137.7 (24.9) | 71 (13) | 25.7 (5.5) | 594.2 (155.1) | 16 |

Data presented as mean (standard deviation). %HRmax, percentage of maximum heart rate; n/a, not applicable.
[a] Significant difference between experienced and inexperienced gamers.

Mean %HRmax reached playing Baseball, Tennis and Boxing were significantly lower than the accepted description for moderate activity (>64%) [1]. When engaging in Jogging, the participants reached a moderate %HRmax [mean 71 (SD 13)%; Table 2].

METs reached while playing AVGs are presented graphically in Fig. 1. The mean METs playing Tennis and Baseball were in the very-light-intensity range. Mean MET levels during Boxing were in the light-intensity range [1]. Similar to %HRmax results, MET values recorded during Jogging were in the moderate-intensity range.

A significant difference was found between gaming conditions for both groups ($F = 4.45$, $P = 0.002$ for Wii Sports group; $F = 18.38$, $P < 0.001$ for Wii Fit group). Interactions between gaming condition, sex and previous gaming experience were all non-significant. Tests of between-subject effects revealed no significant effect for sex or previous gaming experience; the interaction between sex and previous gaming experience was not conducted as all participants with previous gaming experience were male. Post-hoc analysis using Bonferonni's correction factor revealed that playing Boxing resulted in significantly higher responses for all variables measured compared with both Tennis and Baseball simulations ($P < 0.05$). Similarly, Jogging resulted in significantly higher responses for all variables measured than Boxing ($P < 0.05$).

As this was a preliminary study, independent *t*-tests were also performed to gain further insight into the results. Results were similar to those reported from the repeated-measures analysis. However, %HRmax and HR reached by experienced players (37%, 72 beats/minute) during Tennis were significantly lower than those reached by inexperienced players (45%, 86 beats/minute; $P = 0.038$ and $P = 0.036$, respectively; Table 2).

## Discussion

For any exercise prescription, the FITT principles apply, whereby there is a need to determine the frequency, intensity,

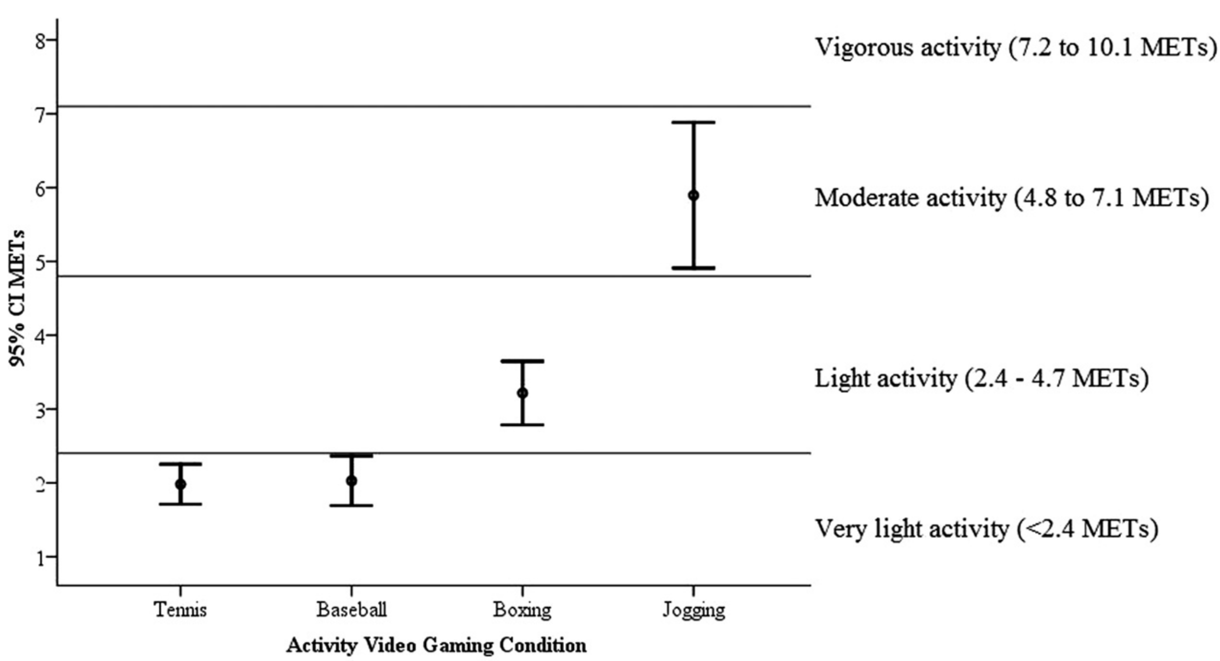


Fig. 1. Energy expenditure while playing active video games in metabolic equivalents (METs). Exercise intensity guidelines are shown. CI, confidence interval.

time and type of exercise. It is not possible to prescribe AVGs without knowledge of their exercise intensity. For AVGs to contribute towards an individual's daily recommended activity, they must require appropriate HRs or levels of energy expenditure [1].

Energy expenditure and HR while playing Wii Sports simulations were comparable with those obtained in previous studies, and add to the body of knowledge in this area [5,16]. As Wii Sports simulations were of a light intensity, they cannot be advocated as partial fulfilment of the 30 minutes of moderate-intensity activity recommended on 5 days per week for young adults.

This is the first study to examine the cardiovascular response to Jogging. Participants consistently reached moderate-intensity HR and MET values while playing Jogging, which may be considered as part of an adult's daily recommended physical activity. Furthermore, the mean %HRmax approached levels where, theoretically, an increase in cardiovascular fitness could be achieved with continuous play [1]. To the authors' knowledge, this is higher than the energy requirements of any other AVG.

Although continuous whole body movement would be expected to result in high energy expenditure and HR, the intensity of Jogging was surprisingly high, with one player reaching %HRmax of 88%. There are several potential explanations for this. Firstly, although it is not a competitive game, there are on-screen characters that the player can overtake if they increase their step rate. This may have motivated some players. Secondly, as most people would not be accustomed to jogging on the spot, this movement may have required greater energy expenditure than expected.

An energy expenditure of approximately 1255 kJ/day has been shown to be effective for weight loss [29]. Provided energy intake remained constant, substituting a sedentary activity for Jogging would achieve this goal in approximately 32 minutes. Although engaging in Wii Sports games may not be prescribed as a means of obtaining moderate-intensity exercise, the benefits of light exercise should be acknowledged [24].

If playing computer games is already part of an individual's lifestyle, which is the case for many young adults [6], converting screen time to exercise could be an effective means of introducing exercise into daily life [24]. Studies have shown that the use of AVGs to reduce sedentary screen time has proven successful [25,26]. It has been shown that watching television can contribute to adiposity by increasing snacking [4], so playing AVGs instead of watching television could reduce this behaviour.

In order to improve or maintain cardiovascular fitness, physical activity of any type, including playing AVGs, must be performed on a regular basis. Interventional studies on adults have shown that the addition of an interactive element to an exercise programme has beneficial effects on attendance, adherence and risk factors associated with cardiovascular disease [27,28]. As this study was cross-sectional in nature, this was not examined.

Sex has been shown to have an effect on energy expenditure while playing AVGs among children [8,13,15] but not adults [12,16]. In this study, no significant difference between the sexes was found in the cardiovascular response to playing AVGs.

The lack of a relationship between gaming experience and the energy cost of playing AVGs is consistent with other studies [14,15]. It is hypothesised that the lower HR and %HRmax seen among experienced gamers playing Tennis may have been due to more efficient controller skill. Tennis requires more controller skill than Boxing, Baseball or Jogging as the players are required to alternate between controlling two on-screen characters rapidly. In 2010, Microsoft released a controller-free AVG console: the Xbox Kinect™. When playing an AVG on this console, controller skill would not be a confounding variable. Research on the potential use of the Xbox Kinect as a form of exercise is warranted.

Interestingly, no difference was found between subjects with and without gaming experience playing a self-paced AVG (Jogging). A limitation is that only one self-paced game was examined. Furthermore, no controller skill was needed to play Jogging. It is hypothesised that games requiring controller skill may be more useful in exposing differences in energy expenditure between those with and without gaming experience.

Having two groups, such that all of the participants did not play all of the games, could be viewed as a limitation. This design reflects the fact that two separate studies took place that were similar in nature, and were therefore analysed and reported as one preliminary study. Other limitations are that the criteria for being an experienced AVG player were basic, and participants' fitness was not examined.

All measurements were taken by the same investigator, who was not blinded. However, to minimise bias, participants were not encouraged, instructions were standardised, and the indirect calorimeter used was valid and reliable.

## Conclusions

To the authors' knowledge, this is the first study to examine the energy requirements of a self-paced Wii game without transition periods. It is also the first study to investigate whether gaming experience affects energy expenditure while playing Wii games.

The results of this study can guide the clinical use of the Wii, and inform its prescription. The Wii may be useful to encourage sedentary adults who enjoy playing video games to become more active. Tennis and Baseball were classed as very-light-intensity activities, and Boxing was classed as a light-intensity activity. Finally, Jogging was classed as a moderate-intensity activity and should be encouraged for those wishing to use AVGs to contribute to their daily activity recommendations. This simulation may represent a welcome, novel method of exercising. AVGs should be encouraged over sedentary activities, but should not replace more intense activities such as sports. Neither sex nor gaming experience appeared to have a significant effect on energy expenditure while playing AVGs.

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*Conflict of interest:* None declared.

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