

# Comparison of Physiological and Metabolic Responses to Playing Nintendo Wii Sports and Brisk Treadmill Walking

by

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*Regular moderate-intensity exercise (e.g. brisk walking) provides health benefits. In the present study, we compared the physiological and metabolic responses of playing the Nintendo Wii Sports tennis, baseball and boxing with self-paced brisk treadmill walking. Ten young-adults (21±1 years; 73.9±12.0 kg; 1.76±0.06 m) played each sport for 10 min with a 5 min rest interval or, in a separate session, walked briskly (6.1±0.6 km·h<sup>-1</sup>) with an equivalent time order wearing the Cosmed K4b<sup>2</sup> metabolic system. In a bout of 10 min, the average values during Nintendo Wii boxing for physiological (i.e. minute ventilation, oxygen uptake and heart rate) and metabolic (i.e. energy expenditure, fat oxidation, carbohydrate oxidation and respiratory exchange ratio) responses were equal to brisk treadmill walking but lower for Nintendo Wii tennis and baseball (P<0.05). It was concluded that the physiological and metabolic responses of Nintendo Wii boxing would allow this game activity to be a viable part of a programme of structured exercise in young-adults to gain health benefits.*

**Key words:** energy expenditure; exercise; video games; oxygen consumption; public health

## Introduction

Major health problems (e.g. Type 2 diabetes, obesity and cardiovascular diseases) in developed societies have been clearly linked with a lack of physical activity (Booth et al., 2000). Although the exact mechanisms responsible for the health benefits are still unknown, evidence in support for the beneficial effects of regular physical activity is substantial (Bauman, 2004). Therefore, opportunities for increasing physical activity of the general population, especially in social-recreational and home environments, need to be stimulated. Although alternative venues of implementing physical activity in our daily lives such as active commuting (Nelson et al., 2008), should be encouraged, a tremendous opportunity may have arisen with the popularity of interactive game play such as the Nintendo Wii Sports. The Nintendo Wii Sports is an interactive video game in which the

player employs a wireless handheld remote controller. The Nintendo Wii senses the movement of the player and translates them into animated caricature screen movements. Such interactive game play may involve significant upper and lower body movements that will raise energy expenditure at least above resting levels (Graves et al., 2007; Maddison et al., 2007; Ridley and Olds, 2008). Many studies have focussed on the energy expenditure of interactive game play or activity promoting games in children and adolescents [e.g. (Graves et al., 2007, 2008; Maddison et al., 2007; Ni Mhurchu et al., 2008; Ridley and Olds, 2008; Straker and Abbott, 2007). However, only a few studies on interactive game play as a physical activity have been performed with young-adults (Segal and Dietz, 1991; Sell et al., 2008; Tan et al., 2002).

Physical activity that is performed with the aim to gain health benefits (e.g. improvement in blood lipid profile, improved glucose tolerance) must need

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Table 1

Time sequence for testing					
Session 1	Brisk walk	rest	Brisk walk	Rest	Brisk walk
Session 2	Wii tennis	rest	Wii baseball	Rest	Wii boxing
Time (min)	0-10	10-15	15-25	25-30	30-40

guidelines for intensity, duration and frequency (Haskell et al., 2007). An example of an exercise that meets those guidelines regarding intensity is brisk walking, it is classified as an exercise of moderate-intensity (Ainsworth et al., 2000). In addition, recent guidelines recommended that such activity is performed for a minimum of 30 min in one bout or bouts that last 10 or more minutes (Haskell et al., 2007). The comparison, as such, of the physiological and metabolic responses of the same individuals during bouts of brisk walking and playing Nintendo Wii Sports could shed light on the viability of Nintendo Wii Sports being part of an exercise programme that may provide health benefits. Interestingly, it is estimated that about 5 million Nintendo Wii Sports have been sold in the UK alone so there may be a need to quantify the physiological and metabolic demands of game play on the Nintendo Wii Sports.

The present study aimed to analyse the physiological and metabolic responses whilst playing games on the Nintendo Wii Sports (i.e. tennis, baseball and boxing) and during brisk treadmill walking with the intention to compare a traditional physical activity with modern game playing. In order to match recommendations for duration of physical activity performed for health benefits, exercise sessions were 30 min with each bout of exercise, i.e. either playing a virtual sport or brisk treadmill walking, lasting 10 min each.

## Materials and Methods

Protocol of the study received institutional approval based on the University of Chichester

Ethics Committee guidelines for research involving human participants and performed according the declaration of Helsinki. A convenience sample of 7 male and 3 female students [(age: 21±1 years (range 20-22); body mass: 73.9±12.0 kg (range 60-98); height: 1.76±0.06 m (range 1.68-1.87; body mass index: 23.7 ± 3.3 kg·m<sup>-2</sup> (range 19.8-29.9)] from the University of Chichester participated and provided written informed consent. Height and body mass were measured to the nearest 0.1 cm and 0.1 kg, respectively, with participants lightly clothed but shoeless. Body mass index (BMI) was calculated as body mass (kg) divided by height squared (m<sup>2</sup>).

Each participant performed two testing sessions on separate days. In one session, participants played on the Nintendo game Wii Sports (i.e. tennis, baseball and boxing) (Table 1). Each sport was played for 10 min with a 5 min rest between sports. Play time was chosen to match recommendations for 30 min as a minimum requirement for physical activity in one session. Participants played at their own level of game play against the same central processing units opponent and received no verbal encouragement. Six participants were novice and the remaining 4 had limited experience on Nintendo Wii Sports. All participants started at the easiest level of competition and the points earned during the games dictated the progress in the game. Testing order of playing sports was not randomised. In the second session, participants were instructed to walk briskly at a self-selected pace on a treadmill (Woodway Ergo ELG 70, Cranlea and Co., Birmingham, UK) (walking speed 6.1±0.6 km·h<sup>-1</sup> (mean±SD), range: 5.0-7.5). The choice of self-paced brisk walking and way of game play ensured ecological validity of the experimental

Table 2

Minute ventilation, oxygen uptake and heart rate for 10 min bouts of brisk treadmill or playing Nintendo Wii Sports

	Walk <sub>0-10</sub>	Tennis <sub>0-10</sub>	Walk <sub>15-25</sub>	Baseball <sub>15-25</sub>	Walk <sub>30-40</sub>	Boxing <sub>30-40</sub>
V <sub>E</sub> , L·min <sup>-1</sup>	36.2±9.6	22.1±7.6*	36.6±9.7	19.7±4.9*	36.7±9.8	32.7±8.9
VO <sub>2</sub> , mL·kg <sup>-1</sup> ·min <sup>-1</sup>	20.3±4.1	10.9±4.2	19.9±4.1	9.7±2.5	19.7±4.2	16.3±4.8**
HR, b·min <sup>-1</sup>	114±14	95±19	117±14	91±13*	116±15	115±19
HR, %HRmax	55±7	46±9	57±7	44±6*	56±7	56±9

Values are means ± SD for 10 participants. V<sub>E</sub>, minute ventilation; VO<sub>2</sub>, oxygen uptake; HR, heart rate; %HRmax, percentage of age-predicted maximal heart rate. Participants performed three bouts of 10 min each of either brisk treadmill walking or playing Nintendo Wii Sports during each testing session. Subscripts in top row indicate exercise time in 40 min protocol with 5 min rest between bouts of exercise. \*, different than boxing and treadmill walking. \*\*, different than tennis and baseball, (P<0.05).

**Table 3**

Energy expenditure, fat and carbohydrate oxidation and respiratory exchange ratio for 10 min bouts of brisk treadmill or playing Nintendo Wii Sports

	Walk <sub>0-10</sub>	Tennis <sub>0-10</sub>	Walk <sub>15-25min</sub>	Baseball <sub>15-25</sub>	Walk <sub>30-40</sub>	Boxing <sub>30-40</sub>
EE, kcal	72±20	38±16**	70±20	34±10***	70±20	57±18
Fat <sub>ox</sub> , g	5.2±2.0	2.6±1.5**	5.2±2.2	2.5±0.8**	5.3±2.3	3.7±1.5
CHO <sub>ox</sub> , g	5.0±4.4	2.7±2.4	4.7±3.4	1.9±1.6	4.3±3.5	4.7±3.4
RER	0.79±0.06	0.79±0.08	0.80±0.06	0.77±0.05	0.79±0.07	0.81±0.07

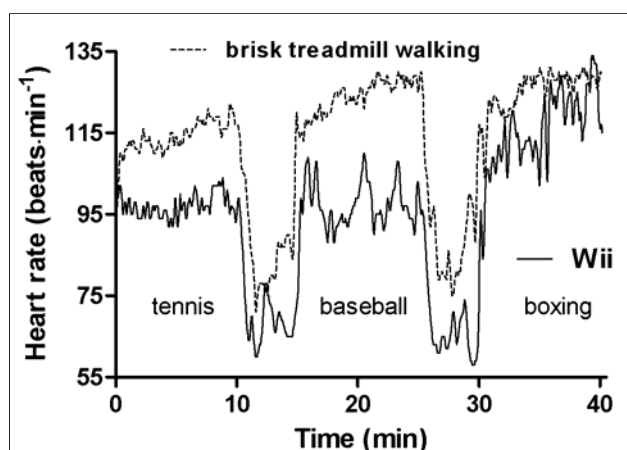
Values are means ± SD for 10 participants. EE, energy expenditure; Fat<sub>ox</sub> and CHO<sub>ox</sub>, amount of fat and carbohydrate oxidized; RER, respiratory exchange ratio. Protein oxidation was neglected. Each participant performed three bouts of 10 min each of either brisk treadmill walking or playing Nintendo Wii Sports during each testing session. Subscripts indicate exercise time in 40 min protocol with 5 min rest between bouts of exercise. \*, different than boxing. \*\*, different than walking, (P<0.05).

design. Time sequence of the walking session, i.e. walks and rest periods, was similar as the time sequence of the session playing sports. All testing was performed in an Exercise Physiology laboratory at the University of Chichester.

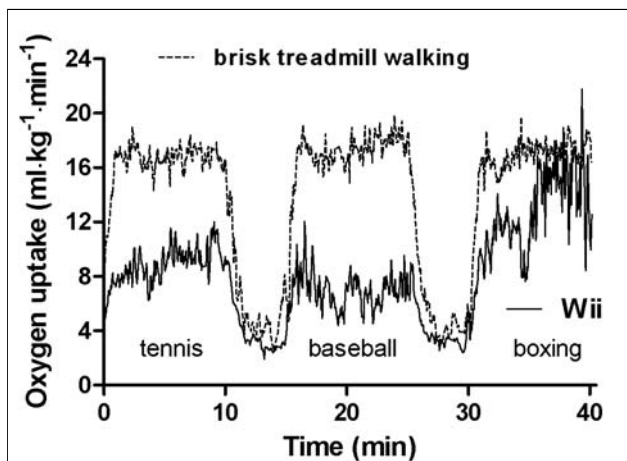
Physiological and metabolic responses were measured with a portable metabolic system (Cosmed K4b2, Cosmed, Rome, Italy). The K4b2 is a lightweight system (~ 800 gram) that attaches to the participant's torso by a harness that allowed them to perform activities with unrestricted lower and upper body movement. Participants breathe through a flexible rubber mask that covers face and nose held in place by a nylon harness. The K4b2 measures volumes of expired air, oxygen consumption and carbon dioxide production on a breath-by-breath basis. Four point calibration of the Cosmed K4b2 was conducted on each testing day according to the manufacturer's guidelines with standard gases of known concentrations (oxygen, O<sub>2</sub>: 14.60%, carbon

dioxide, CO<sub>2</sub>: 5.99%). Respiratory volume was calibrated using a 3L volume syringe. A delay calibration was used in order to match the changes in fractions of expired oxygen (i.e. FEO<sub>2</sub>) and fractions of expired carbon dioxide (i.e. FECO<sub>2</sub>). Finally, a room air measurement calibration was also conducted before each testing session. Temperature and barometric pressure was also measured and entered into the K4b2. Data from the K4b2 portable unit enters into a Windows based programme that allows automatic calculation of energy expenditure, fat and carbohydrate oxidation. The Cosmed K4b2 measures the contribution of all movements including upper limb movements that may have a substantial contribution to the energy demands of the game play with Nintendo Wii (Graves et al., 2008). The Cosmed K4b2 has been validated over a wide range of exercise intensities (McLaughlin et al., 2001) and has been used previously to measure energy expenditure (Harrell et al., 2005).

Physiological (minute ventilation (VE), oxygen uptake (VO<sub>2</sub>) and heart rate) and metabolic parameters [energy expenditure, fat oxidation, carbohydrate oxidation and respiratory exchange ratio (RER)] from the Cosmed K4b2 were averaged for each 10 min of activity. SPSS 16.0 for Windows was used for statistical analyses. Parameter values were similar for each of the 3 bouts of brisk walking (one-way ANOVA) and, therefore, averaged to provide an overall response for brisk walking. One-way ANOVA with post-hoc paired samples t-tests were used to determine differences for either the physiological or metabolic responses between brisk treadmill walking and playing the Nintendo Wii Sports tennis, baseball and boxing. Significance level was set at p < 0.05.



**Figure 1**  
Heart rate as a function of time for one participant during 3 bouts of 10 min of brisk treadmill walking and 3 bouts of 10 min play on Nintendo Wii Sports tennis baseball and boxing



**Figure 2**  
Oxygen Uptake as a function of time for one participant during 3 bouts of 10 min of brisk treadmill walking and 3 bouts of 10 min play on Nintendo Wii Sports tennis, baseball and boxing. Data is from the same participant depicted heart rate in Figure 1

## Results

Responses of heart rate, oxygen uptake and minute ventilation

An example of a participant's heart rate during brisk treadmill walking and playing Wii Sports tennis, baseball and boxing is presented in Figure 1. In general, the heart rate response for all participants showed a slight upward drift in each 10 min bout of treadmill walking whereas the heart rate response during a bout of 10 min of playing Nintendo Wii Sports tennis, baseball and boxing was more variable. There was a trend for the average heart rate in tennis to be lower than boxing ( $p=0.068$ ) and treadmill walking ( $p=0.058$ ). The average heart rate for baseball was 24 beats and 25 beats lower than boxing ( $p=0.013$ ) and treadmill walking ( $p=0.011$ ), respectively. There was no difference in average heart rate between a 10 min bout of boxing or treadmill walking (Table 2). Minute ventilation was lower for tennis ( $p<0.05$ ) and baseball ( $p<0.05$ ) in comparison to boxing and treadmill walking (Table 2).

An example of an individual's oxygen consumption is shown in Figure 2. Oxygen consumption during brisk walking reached a steady state but was variable during Wii Sports. Boxing had a larger oxygen uptake than tennis ( $p=0.026$ ) and baseball ( $p=0.004$ ) but was similar with brisk treadmill walking ( $p=0.318$ ) (Table 2). Brisk treadmill

walking had higher oxygen uptake than tennis ( $p<0.001$ ) and baseball ( $p<0.001$ ) (Table 2).

Energy expenditure, fat and carbohydrate oxidation and respiratory exchange ratio during 3 bouts of 10 minutes of brisk treadmill walking and playing Wii Sports tennis, baseball and boxing, each for 10 min, are provided in Table 3. No differences were observed for metabolic parameters during each 10 min bout of treadmill walking. Boxing had higher energy expenditure than baseball ( $p=0.019$ ) but was not different than tennis ( $p=0.085$ ) and brisk treadmill walking ( $p=0.503$ ). Brisk treadmill walking had higher energy expenditure than tennis ( $p=0.001$ ) and baseball ( $p<0.001$ ). Fat oxidation was only higher in brisk treadmill walking compared to tennis ( $p=0.004$ ) and baseball ( $p=0.003$ ) with no differences between Nintendo Wii Sports. Carbohydrate oxidation was not different between brisk treadmill walking and Nintendo Wii Sports boxing ( $p=0.085$ ) or between Nintendo Wii Sports. RER values were not different between brisk treadmill walking and Nintendo Wii Sports ( $p=0.714$ ) or between Nintendo Wii Sports. This similarity in respiratory exchange ratio indicates equivalent contributions of fat and carbohydrate oxidation to the total energy expenditure during Wii Sports and brisk treadmill walking. Total energy expenditure and fat oxidation during brisk treadmill walking for 30 min were 63% ( $p<0.001$ ) and 75% ( $p=0.002$ ) higher, respectively, than playing a combination of Nintendo Wii Sports tennis, baseball and boxing for 10 min each.

## Discussion

The present study revealed that the game play of boxing with the Nintendo Wii Sports, an exercise with substantial arm movements, resulted in similar physiological and metabolic responses as brisk treadmill walking. Physiological responses of Nintendo Wii Sports tennis and baseball were lower than boxing and brisk treadmill walking in bouts of 10 min. Our experimental design was chosen to take into account that intermittent exercise in bouts of 10 min can be cumulative when performed throughout the day for health benefits to meet physical activity guidelines by the American College of Sports Medicine and the American Heart Association (Haskell et al., 2007). As far as we know, this is the first study in young-adults on comparison of physiological and metabolic responses of game play Nintendo Wii Sports tennis, baseball and boxing versus self-selected brisk walking speed using the

portable metabolic system Cosmed K4b2. The Cosmed K4b2 has been used frequently in other studies on energy expenditure during physical activity/exercise (Faiss et al., 2007; Slootmaker et al., 2009; Sun et al., 2008). In general, there is agreement that the Cosmed K4b2 is a valid and reliable portable metabolic system (Duffield et al., 2004; McLaughlin et al., 2001; Pinnington et al., 2001) across a range of exercise intensities.

Brisk treadmill walking is considered a moderate-intensity exercise (Ainsworth et al., 2000). Although our participants were instructed to walk briskly at a self-selected pace, the recorded physiological and metabolic responses confirm that this resulted for our participants in an exercise of moderate-intensity. Firstly, the heart rates were found to be 55-57% of age-predicted maximal heart rate using the equation by Tanaka et al (2001) ( $55-69\% \max HR$  is recommended by the American College of Sports Medicine/Centres for Disease Control and Prevention, see Pate et al., 1995). Secondly, the average walking speed chosen by our participants was  $6.1 \pm 0.6 \text{ km} \cdot \text{h}^{-1}$  (i.e.  $1.70 \pm 0.18 \text{ m} \cdot \text{s}^{-1}$ , range  $1.39-2.08 \text{ m} \cdot \text{s}^{-1}$ ) and is similar to brisk walking speeds reported in previous studies (e.g. Murtagh et al., 2002). Moreover, the 3 bouts of 10 min of brisk treadmill walking did not result in any physiological observations that may have indicated the development of fatigue. As the arm movements during brisk walking were not controlled, similarity in physiological and metabolic responses during the 3 bouts of walking suggest a similar contribution of arm movements to the overall energy cost of brisk treadmill walking. 'Intensity' of arm movements by Nintendo Wii Sports was not controlled in the present study. Future work could examine whether energy expenditure by 'leisurely' game play such as tennis and baseball could be enhanced by more vigorous arm movements.

Both heart rate and RER values were similar compared with values in a previous study (e.g. Quesada et al., 2000) on 22 year old subjects walking at  $6 \text{ km} \cdot \text{h}^{-1}$ ). The RER values for all activities indicate a tendency for a larger contribution of fat oxidation to the overall energy cost. However, caution is needed when comparing the RER values and the fat and carbohydrate oxidation to other studies due to gender differences in our convenience sample. It is well known, for example, that women tend to use more fat and less carbohydrate than men at relative but low intensities of exercise (Kang et al.,

2007). In addition, a limitation of the present study was that the speed of brisk walking was not standardized according to a known maximal walking speed or maximal oxygen uptake of the participants. However, it is likely that individuals who exercise with brisk walking for health benefits will walk at what they perceive a brisk speed. In elderly individuals, for example, it is known that the instruction to walk briskly will result in higher speeds than is necessary to obtain health benefits (Fitzsimons et al., 2005) but such information is not available for young-adults.

Graves et al (2007, 2008) examined the physiological responses and energy expenditure of game play with Nintendo Wii Sports, albeit in adolescents. These authors also reported higher values for oxygen uptake, heart rate and energy expenditure for boxing compared to tennis (Graves et al 2008). Furthermore, Graves et al (2008) examined the contribution of upper limb and total body movements to the overall energy cost while playing Nintendo Wii Sports in adolescents. We used young-adults as participants as the classification of brisk walking as a moderate-intensity exercise is based on Ainsworth et al (2000) compendium of physical activities and valid for young-adults but not for adolescents. Interestingly, data on energy expenditure by Graves et al (2007, 2008) for tennis and boxing are similar with the findings of the present study. Graves et al (2007) found that playing the active video game Wii Sports resulted in energy expenditure values of  $198.1 \pm 33.9 \text{ J} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  for Wii Sports boxing and  $202.5 \pm 31.5 \text{ J} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  for Wii Sports tennis using the intelligent device for energy expenditure and activity system (IDEEA). As the IDEEA system may not take into account significant contributions of arm movements, Graves et al (2008) used in another study on Nintendo Wii Sports a portable indirect calorimetry system (MetaMax 3B) and reported similar values for tennis ( $200.5 \pm 54.0 \text{ J} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) but now higher values for boxing (i.e.  $267.2 \pm 115.8 \text{ J} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ). Interestingly, the energy expenditure values in the present study for playing Wii Sports were  $215.8 \pm 92.9 \text{ J} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  for tennis and  $293.6 \pm 106.5 \text{ J} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  for boxing and comparable to values in Graves et al (2008). Comparable observations for heart rate and oxygen uptake were reported for adults playing Wii Sports boxing (Barkley and Penko, 2009). In contrast, an energy expenditure of  $2.67 \pm 0.95 \text{ kcal} \cdot \text{h} \cdot \text{kg} \text{ body weight}^{-1}$

was reported for adults playing Wii Sports boxing (Lanningham-Foster et al., 2009) which is lower compared to our study (mean value:  $4.71 \pm 1.40$  kcal·h·kg body weight<sup>-1</sup>). However, caution is required when comparing studies on interactive video games as fitness level of participants, voluntary effort, game experience, instructions provided, and verbal encouragement may influence the outcome with some of these factors difficult to standardize. Future studies are encouraged to examine the energy expenditure of interactive whole-body game play in schools and competitive settings. The popularity of interactive video games

requires prospective studies in larger samples to examine whether voluntary play with interactive video games can provide health benefits.

### Conclusion

Virtual game play with Nintendo Wii Sports boxing is an exercise with physiological and metabolic responses matching those of brisk treadmill walking. Nintendo Wii Sports boxing may provide health benefits when played regularly as part of a structured exercise programme.

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