Original Research

Wii, Kinect, and Move. Heart Rate, Oxygen Consumption, Energy Expenditure, and Ventilation due to Different Physically Active Video Game Systems in College Students

KRISTA S. SCHEER*[1], SARAH M. SIEBRANT*[1], GREGORY A. BROWN‡[1], BRANDON S. SHAW‡[2], and INA SHAW‡[2, 3]

[1]Human Performance Laboratory, Department of Health, Physical Education, Recreation and Leisure Studies, University of Nebraska Kearney, Kearney, NE, USA; [2]Department of Sport and Movement Studies, University of Johannesburg, Gauteng, REPUBLIC of SOUTH AFRICA, [3]Office of the Deputy Pro Vice-Chancellor: Research, Monash South Africa, Gauteng, REPUBLIC of SOUTH AFRICA

*Denotes undegraduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 7(1): 22-32, 2014. *Nintendo Wii, Sony Playstation Move*, and *Microsoft XBOX Kinect* are home video gaming systems that involve player movement to control on-screen game play. Numerous investigations have demonstrated that playing Wii is moderate physical activity at best, but Move and Kinect have not been as thoroughly investigated. The purpose of this study was to compare heart rate, oxygen consumption, and ventilation while playing the games *Wii* Boxing, *Kinect* Boxing, and *Move* Gladiatorial Combat. Heart rate, oxygen consumption, and ventilation were measured at rest and during a graded exercise test in 10 males and 9 females (19.8 ± 0.33 y, 175.4 ± 2.0 cm, 80.2 ± 7.7 kg,). On another day, in a randomized order, the participants played *Wii* Boxing, K*inect* Boxing, and *Move* Gladiatorial Combat while heart rate, ventilation, and oxygen consumption were measured. There were no differences in heart rate (116.0 ± 18.3 vs. 119.3 ± 17.6 vs. 120.1 ± 17.6 beats/min), oxygen consumption (9.2 ± 3.0 vs. 10.6 ± 2.4 vs. 9.6 ± 2.4 ml/kg/min), or minute ventilation (18.9 ± 5.7 vs. 20.8 ± 8.0 vs. 19.7 ± 6.4 L/min) when playing Wii boxing, Kinect boxing, or Move Gladiatorial Combat (respectively). Playing *Nintendo Wii* Boxing, *XBOX Kinect* Boxing, and *Sony PlayStation Move* Gladiatorial Combat all increase heart rate, oxygen consumption, and ventilation above resting levels but there were no significant differences between gaming systems. Overall, playing a "physically active" home video game system does not meet the minimal threshold for moderate intensity physical activity, regardless of gaming system.

KEY WORDS: Energy metabolism, exercise, health promotion, physiology, user-computer interface

INTRODUCTION

The development of a new generation of "physically active" video games, (such as: *Nintendo Wii*, *Microsoft XBOX Kinect*, and *Sony PlayStation Move*) presents an intriguing opportunity to increase physical activity by converting a primarily sedentary pastime into an active behavior. A hallmark of health promoting exercise is that it results in an increase in ventilation, heart rate, oxygen consumption, and thus energy expenditure (2, 13), so playing a physically active video game is being considered as a form of exercise. Playing a physically active video game may increase energy expenditure 2-4 fold compared to a traditionally sedentary video game in children and adults (10-12, 16-20). There are a number of factors that can influence the magnitude of increase in energy expenditure above resting levels while playing physically active video games, such as the game playing experience of the person playing the game (24), the game being played (19, 20; 25), and whether the game requires 1 hand or 2 hands or the whole body to control on-screen play (12; 20). O'Donovan reported that energy expenditure and heart rate are higher when playing against another person rather than against the game system (20), but McWha et al. (18) observed no differences in heart rate, oxygen consumption, or energy expenditure when the game is played against another human or the computer opponent. Furthermore, the social setting in which the game is played can alter the interest in and level of exertion during active video game play (22). Thus, the level of physical activity elicited while playing a physically active video game can be influenced by a myriad of factors including (but not limited to) whether it is a one or two handed game, the experience level of the player, and the social setting of game play.

In November 2010, *Sony* introduced the *Move* system for the *PlayStation* 3 gaming system and *Microsoft* introduced the *Kinect* system for the *XBOX* gaming system. The *Move* system seems to be very similar to the *Nintendo Wii* in its use of motion sensitive controllers, only with greater sensitivity by incorporating a motion sensitive camera and glowing orbs on the ends of the handheld controller, allowing more precise control of the game play. The *Kinect* system uses no handheld controller; rather, it utilizes a camera system to capture a player's movement and then translates those movements onto the screen. The majority of research evaluating energy expenditure while playing physically active video games has focused on the *Nintendo Wii* game system (10-12, 16-19). There has been much less evaluation of energy expenditure during game play while using the *Microsoft Kinect* (20, 25), and there seems to have been no evaluation of energy expenditure during game play while using the *Sony Move*. It was therefore hypothesized that due to the similarity of game play between *Nintendo Wii* and *Sony Move*, these gaming systems would elicit similar levels of physical activity. However, it was hypothesized that the lack of handheld controller by the *Microsoft Kinect* would provide for greater freedom of movement and higher levels of physical activity than *Wii* or *Move* (20). Finally, based on previous observations from this laboratory (18), it was hypothesized that a human or computer opponent would not alter the level of physical activity.

Therefore, the purpose of this research project was to assess the effects of playing similar games using the *Nintendo Wii*, *Sony Move*, and *Microsoft Kinect* on heart rate, ventilation, oxygen consumption, and energy expenditure when competing against a computer or human opponent in college aged adults. The resulting data for oxygen consumption were also used to compare playing *Nintendo Wii*, *Sony Move*, and *Microsoft Kinect* to guidelines for moderate intensity health promoting physical activity.

METHODS

In order to assess the effects of playing *Nintendo Wii*, *Sony Move*, and *Microsoft Kinect* on heart rate, ventilation, oxygen consumption, and energy expenditure when competing against a computer or human opponent in college aged adults, 19 college students were asked to participate in this study. Each participant was assessed for body composition for descriptive purposes, and was assessed for maximal aerobic (VO_2max) capacity in order to determine the relative intensity of playing the active video games. On another day, each participant played hand to hand combat style games that required similar hand movements such as punching, thrusting, and blocking for 8 minutes using the *Nintendo Wii*, *Sony Move*, and *Microsoft Kinect* while heart rate, ventilation, oxygen consumption, and energy expenditure were measured using a metabolic cart. The order of game play was randomized with each participant playing in each of 6 conditions (*Wii* vs. human, *Wii* vs. computer, *Move* vs. human, *Move* vs. computer, *Kinect* vs. human, *Kinect* vs. computer). Data for heart rate, ventilation, oxygen consumption, and energy expenditure were analyzed using a three way (Gender X Opponent X Game) repeated measures ANOVA with a p value of 0.05 and a student Newman Keuls posthoc comparison. In order to determine if playing *Nintendo Wii*, *Sony Move*, or *Microsoft Kinect* could be considered to be health promoting physical activity, the guidelines that moderate intensity physical activity should induce heart rate and oxygen consumption equal to or greater than 50% of maximal, or should be 3 or more metabolic equivalents of task (METs) were used (1; 14).

Participants
Nineteen, apparently healthy male and female college students (Table 1), free from chronic disease or contraindications to exercise (as determined by a detailed written medical history), were recruited through word of mouth for this study. Participants were informed of the potential risks of this project and signed a document of informed consent prior to participation. This project was approved by the Institutional Review Board at the University of Nebraska at Kearney.

Table 1. Subject descriptive data.

	Males (n = 10)	Females (n = 9)	
Age (y)	20.1 ± 0.4	19.8 ± 0.3	
Body Height (cm)	1.80 ± 0.02	1.70 ± 0.02	*
Body Mass (kg)	85.7 ± 6.5	70.1 ± 5.0	*
Percent Body Fat	23.4 ± 2.9	34.2 ± 3.3	*
VO_{2max} (ml/kg/min)	49.1 ± 2.7	33.9 ± 22	*

Data are means ± SEM. * indicates significant different between genders ($p<0.05$).

Protocol
For descriptive purposes, the participants were assessed for body composition. First, body mass was measured using a digital scale (PS 6600ST, Befour Inc, Saukville WI) and height was measured using a stadiometer (Model 707, Seca, Hamburg, Germany). Then body composition was measured using a Dual-Energy X-Ray Absorptiometry (DEXA; DPX-IQ, Lunar Corp, Madison, WI). The participants were asked to wear comfortable clothing with minimal metal snaps, buttons, or zippers

and to remove all jewelry to facilitate accurate measurement of body composition.

In order to measure the aerobic fitness of the participants, and also to facilitate the relative exercise value of physically active video game play, the participants were measured for maximal oxygen consumption (VO_2max). The participants underwent a Bruce Ramp Protocol (29) on a treadmill to measure VO_2max. First, the participants put on a HR monitor (E600, Polar Electro, Oy, Finland) and then sat for 5 minutes in order to record resting HR. Participants were then connected to the metabolic cart (True One 2400, Parvomedics, Sandy, UT) using a facemask (NRB1, Hans Rudolph Inc., Kansas City, MO) and began by walking on the treadmill (425C, Trackmaster Treadmills, Newton, KS) at 1.7 mph with a 10% grade. The treadmill speed and grade gradually increased in small increments every 30 seconds so that every three minutes the speed had increased by 0.8 mph and the grade by 2%. Data for VO_2 and heart rate were measured continuously and then averaged over 20 second intervals by the Parvomedics software. The VO_2max test was terminated when at least 2 of the following criteria were met: VO_2 or HR decreased or remained unchanged in response to increases in workload (as displayed at the end of each 20 second averaging interval), a respiratory exchange ratio value of 1.14 and/or a rating of perceived exertion of 20 was reached on the Borg 6-20 rating of perceived exertion scale (2). All fitness testing and game play occurred indoors under conditions that were as consistent as possible (21.5 ± 0.3 Celsius, 63.9 ± 4.7% humidity, and 702.4 ± 2.0 mmHg). Temperature, humidity, and barometric pressure were measured (Fisherbrand Traceable Digital Barometer, Fisher Scientific, Pittsburgh, PA) before each session when the metabolic cart was calibrated.

The active video games used in the project were *Nintendo Wii* Sports Boxing (Wii), *Microsoft Kinect* Boxing (Kinect), and *Sony PlayStation Move* Gladiatorial Combat (Move). These games were selected because it has been observed that *Wii* Boxing elicits the highest level of energy expenditure of the non-dancing games (such as Wii Tennis or Wii Bowling) (12; 19; 20), so a hand to hand style combat game should result in the greatest exercise stimulus from all 3 gaming systems. However, at the time this project was initiated, no boxing game was available for the *Move* system but Gladiatorial Combat uses movements of both the hands and upper body to control swordplay (such as thrusting, dodging, blocking, and slicing) that are comparable to the hand and upper body movements (punching, dodging, and blocking) in the boxing games. On a separate day from the body composition and fitness testing, the subjects reported to the Human Performance Laboratory for the measurement of heart rate, ventilation, oxygen consumption, and energy expenditure to physically active video game play. This visit occurred at least 24 hours and not more than 14 days after the fitness assessment. Participants were in a seated position for 10 minutes before beginning game play while the researchers provided verbal instructions. When playing the video game, subjects played each game for eight minutes with the heart rate monitor and metabolic cart attached. The order of game play (human or computer opponent; Wii, Kinect, or Move) was randomized and each subject played each of the six possible combination for eight minutes with two minutes of rest between each game play condition. Eight minutes of game time was utilized as this should be sufficient time to obtain adequate measurements of the physiologic response to active video gaming, and also because previous investigations have reported that the light to moderate intensity physical activity of video game play does not seem to produce fatigue in participants when played in 8-10 minute intervals even when multiple games are played sequentially (18; 19). The randomization occurred by having the subject roll a six sided die and used the following table to assign the order of game play (Table 2). After each eight minute gaming session, the subject again rolled the die to determine the next gaming session, and the die was rolled again if a previously used condition was returned. The human opponent during those phases of testing was one of the researchers (K.S. or S.S.). Prior to engaging in game play the participants were given verbal instructions as well as on-screen demonstration on how to the play the games, how to use the controllers or move their body to control on-screen play, and the participants were also instructed to do their best. But the participants were not given information on specific gaming strategies. During the gaming trials some conversation between the researchers and the participants occurred to assure there were no unpleasant side effects occurring (e.g. headaches, nausea, or dizziness), but no verbal encouragement or "trash talking" occurred.

Statistical Analysis

After allowing for 3 minutes of game play in order for the participants to attain steady state, the average heart rate, ventilation, oxygen consumption, and energy expenditure for the final 5 minutes of each eight minute gaming session were used for statistical comparison. Heart rate, ventilation, oxygen consumption, and energy expenditure were analyzed using a three way (gender [male or female] by opponent [human or computer] by game [*Wii*, *Kinect*, or *Move*]) repeated measures of analysis of variance with a p value of 0.05 (Sigma Stat 10, SPSS Inc, Chicago, IL). Significant main effects or interaction effects were identified using a student Newman-Keuls posthoc comparison. Data are presented throughout the manuscript as means ± SEM.

Table 2. Randomization chart for the order of game play. The number represents the number shown when a 6 sided die was rolled and the corresponding to be game played.

Number Rolled	Opponent and Game
1	Human Wii Boxing
2	Computer Wii Boxing
3	Human Kinect Boxing
4	Computer Kinect Boxing
5	Human Move Gladiator Combat
6	Computer Move Gladiator Combat

RESULTS

The males had a higher ($P<0.05$) VO_2max than did the females (Table 1). The males were also taller ($P<0.05$), had larger body mass ($P<0.05$), and lower percent body fat ($P<0.05$) than the females.

Oxygen Consumption, Percent VO_2max, and Energy Expenditure in 10 college aged males and 9 college aged females when playing hand to hand combat style games using three different video game systems against a human or computer opponent. There were no differences between genders, so the data are shown as pooled for males and females.

Table 3. Oxygen consumption, percent VO_2max, and energy expenditure.

	Oxygen Consumption (ml/kg/min)	Percent VO_2max	Energy Expenditure (kcal/min)
	Mean $\pm$ sem	Mean $\pm$ sem	Mean $\pm$ sem
Wii C	9.3 ± 0.9	23.5% ± 2.8%	3.5 ± 0.3
Wii H	9.2 ± 0.5	23.8% ± 2.0%	3.4 ± 0.2
Kinect C	10.6 ± 0.6	26.6% ± 2.3%	4.3 ± 0.4
Kinect H	10.5 ± 0.6	26.2% ± 2.2%	4.1 ± 0.3
Move C	9.8 ± 0.7	25.1% ± 2.0%	3.8 ± 0.3
Move H	9.4 ± 0.5	24.4% ± 1.9%	3.7 ± 0.3

Notes. C= computer, H= human

There were no differences in oxygen consumption between males and females while playing Wii, Kinect, or Move, so the data are presented as pooled data for both genders (table 3). Resting oxygen consumption was 4.33 ± 0.14 ml/kg/min, and oxygen consumption during game play was higher ($P<0.05$) than resting in all game play conditions. There were no differences in oxygen consumption between Wii, Kinect, or Move, and there were no differences in oxygen consumption between a human or computer opponent. Similarly, there were no differences in the percentage of VO_2max elicited by playing Wii, Kinect, or Move, and there were no differences between a human or computer opponent (table 3).

There were no differences in energy expenditure between males and females while playing Wii, Kinect, or Move, so the data are presented as pooled data for both genders (table 3). Resting energy expenditure 1.70 ± 0.11 kcal/min, and energy expenditure during game play was higher ($P<0.05$) than resting in all game play conditions. There were no differences in energy expenditure between Wii, Kinect, or Move, and there were no differences in energy expenditure between a human or computer opponent.

There were no differences in heart rate between males and females while playing Wii, Kinect, or Move, so the data are presented as pooled data for both genders (table 4). Resting heart rate was 84.02 ± 1.82 beats/min, and heart rate during game play was higher ($P<0.05$) than resting in all game play conditions. There were no differences in heart rate between Wii, Kinect, or Move, and there were no differences in heart rate between a human or computer opponent. In order to exemplify the lack of difference between gaming systems, using the overall mean heart rates for *Wii* Boxing against the computer (114.5 beats/min) vs. *Kinect* Boxing against the human (119.6 beats/min), the pooled standard deviations for both conditions (18.4 beats/min), a power of 80%, and an alpha of 0.05 it would take 103 subjects for the difference to reach significance.

Heart rate and minute ventilation in 10 college aged males and 9 college aged females when playing hand to hand combat style games using three different video game systems against a human or computer opponent. There were no differences between genders, so the data are shown as pooled for males and females.

There were no differences in minute ventilation between males and females while playing Wii, Kinect, or Move, so the data are presented as pooled data for both genders (table 4). Resting minute ventilation was 11.12 ± 0.44 l/min, and minute ventilation during game play was higher ($P<0.05$) than resting in all game play conditions. There were no differences in minute ventilation between Wii, Kinect, or Move, and there were no differences in minute ventilation between a human or computer opponent.

Table 4. Heart rate and minute ventilation.

	Heart Rate (Beats/min)			**Minute Ventilation (l/min)**		
	mean		sem	mean		sem
Wii Computer	114.5	±	4.6	18.9	±	1.6
Wii Human	117.6	±	4.3	18.9	±	1.2
Kinect Computer	119.0	±	4.3	21.2	±	2.1
Kinect Human	119.6	±	4.4	20.4	±	1.8
Move Computer	120.0	±	4.6	19.9	±	1.7
Move Human	120.3	±	4.1	19.4	±	1.4

Notes: data are means ± sem

DISCUSSION

The primary findings of the present data indicate that minute ventilation, heart rate, oxygen consumption, and energy expenditure are all increased similarly above resting values by playing *Nintendo Wii* Boxing, *XBOX Kinect* Boxing, *and Sony PlayStation Move* Gladiatorial Combat. However, the intensity level of while playing *Nintendo Wii* Boxing, *XBOX Kinect* Boxing, *and Sony PlayStation Move* Gladiatorial Combat does not meet established guidelines for health promoting exercise. These data further indicate that the presence (*Wii*, *Move*) or absence (*Kinect*) of a handheld motion sensitive controller does not alter the amount of physical activity required to play an "Exergame", which contradicts the hypothesis that the presence or lack of a handheld controller influences the level of physical activity. The present data also suggest that the presence (*Kinect*, *Move*) or absence (*Wii*) of a motion capturing camera does not alter the amount of physical activity required to play an "Exergame", supporting the hypothesis that the similarity of game play between the *Wii* and *Move* will result in no difference in physical activity between these gaming systems. Furthermore, in support one of the hypotheses prompting this research, there were no differences in the physiological response to active video game play against a human or computer opponent. The present data are important to consider as exercise interventions using physically active video games are designed and implemented in numerous environments including family homes, schools, retirement facilities, and other locations.

Previous evaluations of the level of physical activity while playing physically active video games have used accelerometry (11, 12, 16, 22), indirect calorimetry (10, 17, 18, 20, 24, 25, 27), or a calorimetric chamber (19). In the present investigation the physiologic responses (heart rate, ventilation, oxygen consumption, and energy expenditure) to physically active video game play were measured by indirect calorimetry. All of the measured physiological responses may increase or decrease based upon the frequency of muscle contractions and the quantity of muscles involved in the activity (15). Furthermore, the level of mental stimulation can also alter the physiologic responses measured in this project (3, 7, 23). Although playing a video game may be mentally stimulating, previous investigations have demonstrated no difference in heart rate, ventilation, oxygen consumption, or energy expenditure between resting conditions and playing a typical, sedentary style video game (12, 17). Similarly, playing an active video game that requires the use of 1 hand elicits less physical activity than playing a two handed game, which elicits less physical activity than playing a video game that requires whole body movement (12, 17, 20, 27). In the present research, all of the games required the use of 2 hands to control on-screen game play, but no jumping, stepping, or other body movement were required. The lack of difference in heart rate, ventilation, oxygen consumption, and energy expenditure between *Nintendo Wii* Boxing, *XBOX Kinect* Boxing, *and Sony PlayStation Move* Gladiatorial Combat is noteworthy in that it suggests that the presence (*Wii*, *Move*) or absence (*Kinect*) of a handheld motion sensitive controller or the presence (*Kinect*, *Move*) or absence (*Wii*) of a motion capturing camera does not alter the amount of physical activity required to play a physically active video game. Instead, it seems as though whole body movement (such as in dancing or jumping games) or the number of hands being used (10, 12, 19, 20, 27) are the main determinants of energy expenditure while playing physically active video games.

Similar to McWha et al. (18), the present research indicates that playing against a human or computer opponent does not alter the physiologic response to physically active video game play. However, O'Donovan et al. (20) reported that playing against another person compared to single player mode during Wii Boxing mode increases the physical exertion while playing physically active video games. The overall levels of physical exertion reported by McWha et al. (18), O'Donovan et al. (20), and the present investigation are all similar (VO_2 ~10-12 ml/kg/min), so it does not seem that the overall level of physical activity induced by physically active video games was different between these investigations. However, the participants in the present investigation and in McWha et al. (18) did not engage in "trash talking" when playing against a human opponent while more player interaction occurred in the research by O'Donovan et al. (20), which may explain why measured physical exertion was observed to be higher in multi-player in the research by O'Donovan et al. Taking all of these data together, it suggests that a human opponent may present a variable level of stimulation to physical activity based upon the relationship between the players and the extent of interpersonal competition (8, 24).

Generally speaking, health promoting moderate intensity physical activity (roughly equal to brisk walking) is that which causes notable increases in heart rate, breathing, and oxygen consumption (14). More specific recommendations state that health promoting moderate intensity physical activity should induce heart rate and oxygen consumption equal to or greater than 50% of maximal, or should be 3 or more metabolic equivalents of task (METs) (1, 14). Although playing the physically active video games in the present research increased heart rate, oxygen consumption, ventilation, and energy expenditure, these physically active video games only elicited ~25% of VO_{2max} or ~2.8 METs, which does not meet the minimal intensity for health promoting exercise (1, 14). Miyachi et al. (19) used a metabolic chamber to evaluate the energy expenditure of participants while they played 68 different physically active video games, most of these using the Wii Fit balance board, and observed that only 1/3 of these activities elicited 3-6 METs and the rest elicited less than 3 METs. Previous research has also indicated that while playing physically active video games requires more exertion than playing a sedentary video game (which is not different from resting), playing a physically active video game is unlikely to meet the criteria for health promoting moderate intensity physical activity (11, 12, 17-19, 27).

One limitation to the present investigation is that the metabolic cart used was a traditional metabolic cart that requires the players to be "tethered" by a hose to stationary object. Thus, using a portable metabolic cart (e.g. Cosmed K4b^2) or metabolic chamber might allow for greater freedom of movement while playing the video games, and thus elicit higher levels of physical activity. For instance the physical activity for *Wii* Boxing in the present investigation (~2.6 METs) is slightly lower than previously reported while playing *Wii* Boxing in a calorimetric chamber (~3 METs). Another limitation is that, although similar, boxing (*Wii* and *Kinect*) and Gladiatorial Combat (*Move*) are not the exact same sport, thus comparing boxing on the *Wii* and *Move* might have a different result. Unfortunately, at the time this project was initiated there was not a boxing game available for the *Move* game system.

Overall, there has been a considerable amount of research evaluating physically active video games and their effect on energy expenditure and physical activity levels (11, 12, 17-19, 27). However, to our knowledge there has not been much evaluation of the effects of physically active video gaming as a form of habitual exercise on measures of health and fitness, such as Owens et al. (21). There also exist a wide number of video games that require whole body movement (e.g. *Kinect Adventures* Obstacle Course), which very likely elicit higher levels physical activity and could thus be more likely to promote health if played regularly.

The present results indicate that when using similar style 2 handed combat games, the gaming system used does not alter the amount of physical activity elicited by physically active video games. Also, playing against a human opponent with minimal interaction presents the same stimulus for physical activity as does a computer opponent. So, while playing physically active video games may be beneficial for rehabilitation from stroke (5; 6) and for assisting in the development of motor control for individuals with neuromuscular disorders (9; 26; 30). The use of physically active video games may also be beneficial as a starting point for an exercise program in those who have previously been engaged in little to no leisure time physical activity or as an alternative activity in physical education classrooms (4; 10; 28). However, the present results, along with numerous previous investigations (11; 12; 17-19; 27) suggest that playing physically active video games are unlikely to be a suitable alternative to other forms of exercise when one is trying to meet the established criteria for engaging in moderate intensity health promoting exercise.

ACKNOWLEDGEMENTS
This project was supported by the Undergraduate Research Fellows Program at the University of Nebraska at Kearney.

REFERENCES

1. American College of Sports Medicine Position Stand. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. Med Sci Sports Exerc 30: 975-991, 1998.

2. ACSM's Guidelines for Exercise Testing and Prescription. Philadelphia: Lippincott, Williams, & Wilkins, 2000.

3. Achten J and Jeukendrup AE. Heart rate monitoring: applications and limitations. Sports Med 33: 517-538, 2003.

4. Borja RR. Dance Video Games Hit the Floor in Schools. Education Week 25: 1, 2006

5. Broeren J, Claesson L, Goude D, Rydmark M and Sunnerhagen KS. Virtual rehabilitation in an activity centre for community-dwelling persons with stroke. The possibilities of 3-dimensional computer games. Cerebrovasc Dis 26: 289-296, 2008.

6. Broeren J, Rydmark M, Bjorkdahl A and Sunnerhagen KS. Assessment and training in a 3-dimensional virtual environment with haptics: a report on 5 cases of motor rehabilitation in the chronic stage after stroke. Neurorehabil Neural Repair 21: 180-189, 2007.

7. Byrne NM, Hills AP, Hunter GR, Weinsier RL and Schutz Y. The metabolic equivalent: One size does not fit all. J Appl Physiol 2005.

8. Cherney ID and Poss JL. Sex differences in Nintendo Wii performance as expected from hunter-gatherer selection. Psychol Rep 102: 745-754, 2008.

9. Deutsch JE, Borbely M, Filler J, Huhn K and Guarrera-Bowlby P. Use of a low-cost, commercially available gaming console (Wii) for rehabilitation of an adolescent with cerebral palsy. Phys Ther 88: 1196-1207, 2008.

10. Graf DL, Pratt LV, Hester CN and Short KR. Playing active video games increases energy expenditure in children. Pediatrics 124: 534-540, 2009.

11. Graves L, Stratton G, Ridgers ND and Cable NT. Comparison of energy expenditure in adolescents when playing new generation and sedentary computer games: cross sectional study. BMJ 335: 1282-1284, 2007.

12. Graves LE, Ridgers ND and Stratton G. The contribution of upper limb and total body movement to adolescents' energy expenditure whilst playing Nintendo Wii. Eur J Appl Physiol 2008.

13. Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, Macera CA, Heath GW, Thompson PD and Bauman A. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc 39: 1423-1434, 2007.

14. Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, Macera CA, Heath GW, Thompson PD and Bauman A. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Circulation 116: 1081-1093, 2007.

15. Kenney WL, Costill DL, Wilmore JH and Costill DL. Physiology of Sport and Exercise 5th ed. Champaign, IL: Human Kinetics, 2011.

16. Lanningham-Foster L, Foster RC, McCrady SK, Jensen TB, Mitre N and Levine JA. Activity-promoting video games and increased energy expenditure. J Pediatr 154: 819-823, 2009.

17. Lanningham-Foster L, Jensen TB, Foster RC, Redmond AB, Walker BA, Heinz D and Levine JA. Energy expenditure of sedentary screen time compared with active screen time for children. Pediatrics 118: e1831-e1835, 2006.

18. McWha JA, Horst S, Brown GA, Shaw I and Shaw BS. Metabolic Changes Associated with Playing an Active Video Game Against a Human and Computer Opponent. African Journal for Physical, Health Education, Recreation and Dance 9, Supplement: 219-228, 2009.

19. Miyachi M, Yamamoto K, Ohkawara K and Tanaka S. METs in adults while playing active video games: a metabolic chamber study. Med Sci Sports Exerc 42: 1149-1153, 2010.

20. O'Donovan C, Hirsch E, Holohan E, McBride I, McManus R and Hussey J. Energy expended playing Xbox Kinect and Wii games: a preliminary study comparing single and multiplayer modes. Physiotherapy 98: 224-229, 2012.

21. Owens SG, Garner JC, III, Loftin JM, van BN and Ermin K. Changes in physical activity and fitness after 3 months of home Wii Fit use. J Strength Cond Res 25: 3191-3197, 2011.

22. Paez S, Maloney A, Kelsey K, Wiesen C and Rosenberg A. Parental and environmental factors associated with physical activity among children participating in an active video game. Pediatr Phys Ther 21: 245-253, 2009.

23. Ruttkay-Nedecky I. Mechanisms of the influence of psychic factors on cardiac activity. Act Nerv Super (Praha) 22: 130-137, 1980.

24. Sell K, Lillie T and Taylor J. Energy expenditure during physically interactive video game playing in male college students with different playing experience. J Am Coll Health 56: 505-511, 2008.

25. Smallwood SR, Morris MM, Fallows SJ and Buckley JP. Physiologic responses and energy expenditure of kinect active video game play in schoolchildren. Arch Pediatr Adolesc Med 166: 1005-1009, 2012.

26. Smith ST, Sherrington C, Studenski S, Schoene D and Lord SR. A novel Dance Dance Revolution (DDR) system for in-home training of stepping ability: Basic parameters of system use by older adults. Br J Sports Med 2009.

27. Unnithan VB, Houser W and Fernhall B. Evaluation of the energy cost of playing a dance simulation video game in overweight and non-overweight children and adolescents. Int J Sports Med 27: 804-809, 2006.

28. Warburton DE, Bredin SS, Horita LT, Zbogar D, Scott JM, Esch BT and Rhodes RE. The health benefits of interactive video game exercise. Appl Physiol Nutr Metab 32: 655-663, 2007.

29. Will PM and Walter JD. Exercise testing: improving performance with a ramped Bruce protocol. Am Heart J 138: 1033-1037, 1999.

30. Yalon-Chamovitz S and Weiss PL. Virtual reality as a leisure activity for young adults with physical and intellectual disabilities. Res Dev Disabil 29: 273-287, 2008.