Original Research

Greater Physiological Responses While Playing XBox Kinect™ Compared to Nintendo Wii™

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ABSTRACT

International Journal of Exercise Science 8(2): 164-173, 2015. Increasing popularity of active video game use as a mode of physical activity prompted this investigation into the physiological differences to playing the Nintendo Wii™ and XBox Kinect™. Differences in motion capture technology between these systems suggests that using one may result in different movement patterns, and therefore physiological responses, than the other. The purpose of this study was to compare the average (10 minute) and peak heart rate (HR, bpm), oxygen consumption (VO_2 $mL \cdot kg^{-1} \cdot min^{-1}$), and energy expenditure (EE, $kcal \cdot kg^{-1} \cdot hr^{-1}$), while playing Boxing and Just Dance 2 (JD2) on the Wii™ and Kinect™. Fifteen college students (7 female, 8 male) completed 10-minute game sessions for Wii™ and Kinect™ Boxing, and Wii™ and Kinect™ JD2, in random order. Comparisons for average and peak HR, VO_2, and EE were made. Average and peak HR, VO_2, and EE were greater ($p<0.05$) while playing Boxing on the Kinect™ when compared to Boxing on the Wii™. Average and peak VO_2 and EE were greater ($p<0.05$) while playing JD2 on the Kinect™ when compared to JD2 on the Wii™. Peak VO_2 surpassed the moderate exercise intensity threshold only while playing Kinect™ Boxing and Kinect™ JD2. Higher physiological responses were experienced when playing Boxing and JD2 on the Kinect™ versus the Wii™. When using active video games as a form of physical activity, these findings demonstrate that the Kinect™ is a better choice than the Wii™.

KEY WORDS: Energy expenditure, video games, physical activity, college students, oxygen consumption

INTRODUCTION

Regular physical activity is associated with a decreased risk for several chronic disease conditions, such as cardiovascular disease, obesity, hypertension, and certain cancers (5, 8, 21). Results from the 2013 National College Health Assessment state that 38.4% of college students are inactive, while only 48.8% meet the minimum guidelines for physical activity (2). The most recent physical activity recommendations published by the American College of Sports Medicine (ACSM) report that adults should participate in at least 30 minutes of moderate intensity activity at least 5 days per week (3, 6). According to ACSM, moderate-intensity exercise for young healthy adults (between 18 – 65 years of age and free of any known cardiovascular or metabolic disease) is that which results in energy expenditure of between 4.8 and 7.1 metabolic equivalents (METs) or an oxygen uptake (VO_2) of 16.8 – 24.9 mL · kg^{-1} · min^{-1} (3).

For over a decade, the physiological effects of playing active video games (AVGs) and their potential as a means to satisfy physical activity requirements have been studied (4, 7, 9-11, 13-15, 17-20, 22). Playing AVGs has been shown to elicit low to moderate exercise intensity, defined by ACSM as 20%-60% of oxygen uptake reserve or 40%-76% of maximal heart rate (3). Their value as a mode of physical activity warrants investigation as exercising at this level of intensity can assist with weight management, improve cardiovascular function, increase muscle mass and improve bone density (3, 14). Active video games are popular among children, adolescents, and adults (4), and physical activity is encouraged when playing them by integrating the player's body movements with gameplay.

Two of the most popular AVGs, the Nintendo Wii™ (Wii™) and Microsoft XBox Kinect™ (Kinect™), utilize different technologies in relation to how the player interacts with their respective games. The Wii™ uses a hand-held wireless controller that communicates with a sensor bar on or near the video display screen to detect player movements. The controller contains an accelerometer, which detects movement in all three axes of motion, and it communicates with the sensor bar through two infrared beams. All on-screen movement and therefore game scoring is based on the activity of the hand-held controller. The Kinect™, in contrast, does not use a hand-held controller, but instead utilizes an infrared motion sensor and a red-green-blue webcam that are able to create a three-dimensional representation of the person playing the game. While playing the Kinect™, the user's body movement is captured, from head-to-toe, in three-dimensions and therefore scoring is based on whole-body movement.

These differences in motion capturing techniques between the Wii™ and Kinect™ have the potential to affect the way games are played between the two systems. Users of the Wii™ may be more likely to overemphasize movement of the controller in relation to the rest of their body because of the understanding that scoring is solely based on the controller's movement. Conversely, users of the Kinect™ may be more likely to incorporate whole-body movement while playing, knowing that their score or game progress will be rewarded because of that. These differences could translate into significant differences in physiological responses when playing the same game between the two systems.

Research comparing the physiological effects of playing the Wii™ versus the Kinect™ is limited, which is most likely due to the Kinect™ only being made available to the public in November, 2010. Only one study has compared the physiological responses to playing the Wii™ versus the Kinect™ while playing the same game (19). In this comparison, researchers measured average heart rate, oxygen consumption, ventilation, and energy expenditure during eight minutes of game play in 19 college-aged students while playing Wii™ Boxing, Kinect™ Boxing and Sony PlayStation™ Move Gladiatorial Combat. Trends in their data indicated higher physiological responses while playing the Kinect™, however, no significant differences were reported among any of the variables measured. In a study conducted by O'Donovan et al. (14), it was reported that playing Kinect™ Reflex Ridge resulted in greater oxygen consumption when compared to playing Wii™ Boxing during 10-minutes of game play in 14 healthy adults. While this study was successful at identifying the physiological responses to playing the two different games, it did not provide any insight as to whether the motion capture technologies between the Wii™ and Kinect™ alter game play.

In a well-controlled study by Jordan et al. (11), a standard Sony Playstation 2™, Nintendo Wii™, and modified Sony Playstation 2™ (PS2) were compared. The modified PS2 required the user to control the game using a mat, where commands had to be stepped on. This modified control made the user step sideways, forward, or hop to the necessary command. The results from their study showed that the inclusion of lower limb movement increased the physiological responses significantly compared to both the Wii™ and standard PS2 controls. Although this type of whole-body movement is intended when using the Wii™, it is not necessary to gain points or succeed in game play. In another study by O'Donovan et al. (14), researchers observed that subjects playing Wii™ tennis succeeded by using short and sharp 'flicking' movements of the wrist, instead of fully swinging or extending the arm as intended. To our knowledge it is not possible to be rewarded for this type of 'shortcut' activity while playing the Xbox Kinect™.

The importance of understanding whether there are differences in the way the Wii™ and Kinect™ are played lies in the potential of one eliciting a greater physiological response than the other. If so, using that gaming console could result in greater physiological adaptations and energy expenditure. Compared to traditional exercise and sedentary video games, playing AVGs has been found to be preferable and are becoming commonly used in both clinical and rehabilitation settings as an alternate means of physical activity (4, 9, 10). Additionally, if the exercise intensity reached while playing the Wii™ or Kinect™ is considered moderate, playing them could be used to satisfy the recommended physical activity guidelines.

The purpose of this study was to compare the average and peak physiological responses of using the Wii™ and Kinect™ gaming systems while playing Boxing and Just Dance 2 (JD2) on each system. The average response will represent 10-minutes of continuous game play, and the peak will represent the highest value measured during a 10-minute game session. It was hypothesized that playing games on the Kinect™ would elicit significantly higher average and peak heart rate, VO_2, and energy expenditure when compared to playing the same game on the Wii™. The perceived freedom of movement due to lack of a hand-held controller, and the need to move the entire body to achieve the highest score while using the Kinect™ would lead to greater body movement and therefore greater physiological responses.

METHODS

Participants

Fifteen healthy college students (7 women, 8 men) volunteered to participate in this study after being recruited by word-of-mouth. This study received institutional

Table 1. Subject characteristics.

	Overall		Women (n = 7)		Men (n = 8)	
	M	SD	M	SD	M	SD
Age (years)	21.3	1.4	20.9	1.8	21.6	1.1
Weight (kg)	71.4	12.4	65.2	12.5	76.0	10.8
Height (cm)	171.7	7.9	169.4	6.1	173.7	8.9
Body mass index (kgm^2)	24.1	3.7	22.6	3.5	25.2	3.7

Note: M = mean; SD = standard deviation

ethics approval, and subjects were informed as to the risks of the study and provided written informed consent prior to participation. Additionally, subjects completed a health history questionnaire and a PAR-Q to screen for any contraindications to exercise.

Protocol

For each subject, data were collected during one testing session. Upon arrival to the human performance laboratory, body weight and height (Detecto-D439, Cardinal Scales, Webb City, MO) were measured, as reported in Table 1. Subjects were then connected to a metabolic cart (TrueOne 2400, ParvoMedics. Sandy, UT) by use of a two-way breathing valve and mouthpiece (Hans-Rudolf Inc. Shawnee, KS) and fitted with a heart rate monitor (Polar Electro. Oy, Finland). Prior to all tests, the metabolic cart was calibrated in accordance with the manufacturer's specifications. Temperature in the laboratory was maintained at 21 - 23°C and 45 – 55% relative humidity.

Oxygen consumption data were collected using open-circuit spirometry on a breath-by-breath basis. Values for VO_2 were averaged over the 10-minute playing sessions. Heart rate (HR, bpm) was collected continuously and was averaged each 10-minute playing session. Data representing the 'peak' for these variables was correspondingly obtained. To acquire the peak values, a one-minute rolling average was calculated from the 10-minutes of breath-by-breath data and the highest value was used. Energy expenditure (EE), as kilocalories per kilogram body weight per hour ($kcal \cdot kg^{-1} \cdot hr^{-1}$), was calculated using the equation:

$$EE\ (kcal \cdot kg \cdot hr^{-1}) = VO_2\ (mL \cdot min^{-1}) \cdot 4.9\ (kcal) \cdot 60\ min \cdot body\ weight\ (kg)^{-1}$$

Where EE is energy expenditure; VO_2 is oxygen consumption; 4.9 is the constant used to estimate kilocalories utilized per 1000 mL of oxygen consumed (Kenny & Costill, 2011).

The gaming systems used in this study were the Nintendo Wii™ (Nintendo Co. Ltd., Tokyo, Japan) and the Microsoft XBox Kinect™ (Microsoft Inc., Redmond, WA). In random order, subjects completed 10-minutes of continuous gameplay for each of the following: Wii™ Boxing (WB), Kinect™ Boxing (KB), Wii™ Just Dance 2 (WJD2), and Kinect™ Just Dance 2 (KJD2), for a total of 40 minutes of playing time. There was a 8-10 minute break between each game session. The break began with 5-minutes of seated rest, followed by 2-4 minutes of game instruction where the rules of the game were explained and subjects could practice the game. The break then finished with one-minute of standing rest. Data collection began at the beginning of the first round in Boxing, and the beginning of the first dance for JD2. Subjects continued to play each game for 10 minutes. Research technicians operated the gaming systems between opponents (Boxing) and dances (JD2) in order to assure game transitions went as quickly as possible. Subjects did not receive any verbal feedback or strategy tips while playing, or in between games. However, they were instructed to try and achieve the highest score possible. Subjects were not made aware of the nature of the comparisons in this study in order to minimize any potential bias in effort while playing one gaming system versus the other.

The Boxing game on the Wii™ and Kinect™ is a simulated match where the player attempts to knockout or outscore their opponent. There are 90-second rounds with brief pauses in between each round. Additional pauses in game play occur when the opponent is knocked-down or knocked-out, or when the player is knocked-down or knocked-out. These pauses lasted approximately 5-10 seconds for WB and 10-15 seconds for KB. Data collection continued during these pauses. Gameplay was against the computer, and the difficulty level was set at medium for both systems. The boxing game requires mostly upper body movement and rewards the player for punching the computer opponent and for ducking or blocking punches thrown by the opponent. Wii™ Boxing requires the use of the Wii™ Nunchuck. The Nunchuck is a second hand-held controller connected to the primary controller by a 1.07m long cable. It contains a three-axle accelerometer in order to detect motion in all planes. Use of the Nunchuck allows for movement by both hands to be detected during game play. In comparison, Kinect™ Boxing required no hand-held devices, allowing both arms to move freely, and all movement was captured and scored using the three-dimensional motion sensor and web-cam.

Just Dance 2 is a game where players try and achieve the highest score by mimicking the dance moves displayed by an on-screen dancer. Feedback is provided on the screen for each system with a cumulative score, and flashing evaluation of the success of the last dance move. The flashing on-screen feedback could either be 'perfect', 'good', 'ok', or an 'x'. A 'perfect' response results in maximum points for the dance move and indicates the user matched the on-screen dancer to the highest degree. In descending order, 'good,' 'ok,' and 'x' are rewarded with fewer points and indicate the player executed the dance move with a decreasing degree of accuracy. Subjects were instructed to try and achieve the 'perfect' mark as often as possible. On the Wii™, players attempt to follow the whole-body movement of the on-screen dancers, but were to pay special attention to the colored glove the dancers are wearing and attempt to have the Wii™ controller follow the movement of that gloved-hand as closely as possible for the best score. The game screen is the same for both systems, except on the Kinect™ there is a small real-time video 'shadow' of the player dancing on the left side of the screen. This video feedback allows players to match their movement to the on-screen dancers being emulated. The Kinect™ was set to full-body-recognition mode for all data collection. Pauses between songs lasted approximately 10 -15 seconds for both gaming systems and data collection continued during these pauses. The 'difficulty' and 'effort' ratings of the songs used were either 2 or 3 out of a maximum of 3, as rated by the JD2 game.

Table 2. Boxing data.

		Boxing			
		Wii™		Kinect™	
Exercise Variable		M	SD	M	SD
HR (bpm)	Avg	115.4	12.8	124.9*	13.0
	Peak	118.8	14.5	138.0*	20.6
VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)	Avg	10.0	2.7	15.3*	4.5
	Peak	13.8	3.6	22.7*	7.0
EE ($kcal \cdot kg^{-1} \cdot hr^{-1}$)	Avg	3.0	0.8	4.6*	1.4
	Peak	4.2	1.1	6.8*	2.1

Note: HR = heart rate; VO_2 = oxygen consumption; EE = energy expenditure; JD2 = Just Dance 2; Avg = 10-min averaged data; Peak = peak data; M = mean; SD = standard deviation. *$p < 0.05$, Kinect™ is greater than Wii™.

Difficulty refers to the degree of technical skills needed to complete a dance move, while effort refers to the total amount of movement needed to complete the dance. Each subject danced to the same song, which has the same choreography while playing WJD2 and KJD2.

All data were collected in a 3m x 3m space free of obstacles and lined with black tape on the floor. To maximize subject comfort and allow for the greatest freedom of movement, a research technician held-up the expired gas tubing connecting the two-way breathing valve to the metabolic cart, and followed the subject around the gaming space as needed. The games were displayed on a 1.27m plasma television (Panasonic Corporation of North America, Newark, NJ) suspended 1.52m from the ground with the Wii™ and Kinect™ sensors placed approximately 30cm below it. Subjects stood 1.8m – 2.4m from the TV, in the middle of the 3m x 3m playing area, with the metabolic cart positioned to their right, on the edge of the designated playing space. The Wii™ controller and Kinect™ motion sensor were calibrated prior to use for each subject.

Statistical Analysis

Descriptive data (weight, height, age, and BMI) were calculated using Microsoft Excel (Microsoft, Inc., Redmond, WA). Data for VO_2, HR, and EE were analyzed using paired t-tests (SigmaXL, Toronto, Ontario, Canada). The alpha level was set at $p \leq 0.05$.

RESULTS

Fifteen subjects completed data collection for WB, KB, WJD2, and K JD2. Participant data are presented in Table 1. The results for the Boxing game comparisons demonstrate greater average and peak HR, VO_2, and EE for the Kinect™ ($p < 0.05$, Table 2). Subjects playing JD2 on the Kinect™ experienced significantly greater average and peak VO_2 and EE when compared to the Wii™ ($p < 0.05$, Table 3). Heart rate was not different for the WJD2 versus KJD2 comparison ($p > 0.05$). Average values for VO_2 did not reach the threshold for moderate intensity physical activity (16.8 $mL \cdot kg^{-1} \cdot min^{-1}$) for any of the measurements. However, examination of the peak data revealed that while playing the Kinect™ , VO_2 was above this threshold

Table 3. Just Dance 2 data.

		Just Dance 2			
		Wii™		Kinect™	
Exercise Variable		M	SD	M	SD
HR (bpm)	Avg	110.1	14.5	111.5	12.3
	Peak	120.8	15.7	125.4	17.2
VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)	Avg	10.9	3.8	13.7*	3.5
	Peak	15.6	6.1	20.3*	4.2
EE ($kcal \cdot kg^{-1} \cdot hr^{-1}$)	Avg	3.3	1.1	4.1*	1.1
	Peak	4.7	1.8	6.1*	1.3

Note: HR = heart rate; VO_2 = oxygen consumption; EE = energy expenditure; JD2 = Just Dance 2; Avg = 10-min averaged data; Peak = peak data; M = mean; SD = standard deviation. *$p < 0.05$, Kinect™ is greater than Wii™.

at 20.3 $mL \cdot kg^{-1} \cdot min^{-1}$ and 22.7 $mL \cdot kg^{-1} \cdot min^{-1}$ for KJD2 and KB, respectively.

DISCUSSION

The main findings of this study were that HR, VO_2, and EE were greater while playing Kinect™ Boxing versus Wii™ Boxing, which supports the study's hypothesis. Additionally, VO_2 and EE were greater while playing Kinect™ JD2 compared to Wii™ JD2. This result does not support the hypothesis, due to the lack of differences in HR between the gaming systems. Our findings are in agreement with those of O'Donovan et al. (14), who reported that average METs were greater while playing the Kinect™ compared to the Wii™. The results in the present study, however, are more applicable because Boxing and JD2 were compared on both gaming consoles, whereas O'Donovan et al. (14) compared different games, Kinect™ Reflex Ridge and Wii™ Boxing, between the gaming consoles. Their study was limited by the differences in physical demands and body movements required to play and score points in the different games measured.

The consistently higher average and peak physiological responses experienced while playing the Kinect™ are most likely due to greater overall body movement, and therefore the activation of more muscle mass during play. The Kinect™ motion capture system technology may have encouraged the use of a greater amount of the lower limbs in order to gain correct body position and score maximum points. This finding is in agreement with that of Jordan et al. (11), where it was concluded that the inclusion of the lower body leads to increased physiological responses during game play when compared to games that did not encourage such movement.

Peak exercise intensities during Kinect™ game play reached the moderate intensity physical activity level, however, this intensity was not sustained for the duration of the testing sessions, which is likely due to the pauses in game play and nature of the games themselves. This finding is representative of the potential that playing these games on the Kinect™ can elicit high enough physiological demands to serve as a form of moderate intensity physical activity. Further research is needed to better understand how to maximize the duration of this level of response during game play.

The 10-minute averaged data can be classified as low-intensity physical activity (VO_2 < 16.8 mL · kg^{-1} · min^{-1}) for both the Wii™ and Kinect™, which is consistent with previous findings (13, 14, 17-20). It would seem that AVGs are not demanding enough movement to result in moderate-intensity physical activity in healthy populations over extended gameplay situations. This doesn't mean, however, that playing AVGs won't provide some benefit. Participating in regular low-intensity exercise results in a reduced risk for chronic diseases such as cardiovascular disease, diabetes, cancers, hypertension, depression, and premature death in previously sedentary individuals (5, 21). Furthermore, Lazzer et al. stated that if those who currently play sedentary video games were to replace that time playing AVGs, EE would increase by a minimum of 4.5% (12). O'Donovan et al. (14) and Owen et al. (16), noted that healthy individuals who satisfy the daily activity recommendations still suffer from sedentary time spent in front of a screen and that playing AVGs would serve a means to minimize this behavior.

Based on the data in this study, 10-minutes of playing KB and KJD2 resulted in 36% and 53% increased EE when compared to the WJD2 and WB, respectively. This would equal the expenditure of an additional 112 kcal while playing KB and an additional 56 kcal burned while playing KJD2 each hour for a 70kg college-aged individual when playing the Kinect™ instead of the Wii™. With reports that the average video game player spends between 8 and 18 hours per week playing games (Education database online, Entertainment Software Rating Board), the use of the Kinect™ would result in substantial increases in energy expenditure when compared to playing the Wii™, and an even greater difference when compared to playing sedentary video games or resting (see Figure 1). The benefits of increased energy expenditure are associated with improved health, decreased risk of chronic disease, decreased mortality, and improved body composition.

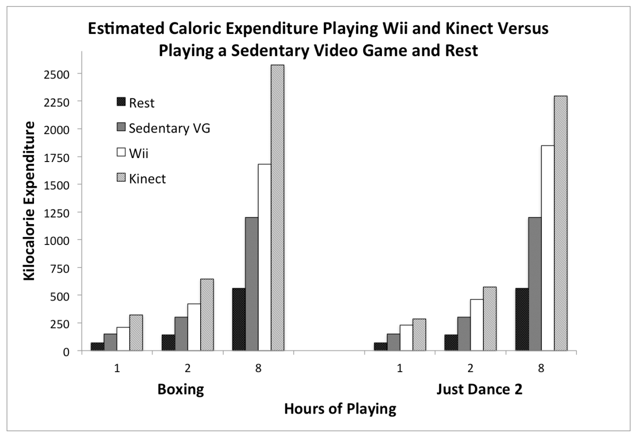

Figure 1. Estimation of kilocalories utilized while playing Boxing and JD2 on the Kinect™ and Wii™ based on the results of this study, compared to resting caloric expenditure and standard sedentary video game play[20] in a 70kg individual. The 8-hour comparison represents the minimum reported average time of gaming for regular video game players.

Finally, AVGs are proving to have application in clinical settings. Numerous studies have noted the impact AVGs have on clinical populations, with Holmes et al. (9) observing high intensity exercise was achieved by individuals with cystic fibrosis when using the Kinect™. Hurkmans et al. (10) stated that Wii™ Sport used in both tennis and boxing modes elicited moderate intensity exercise in adults with bilateral spastic cerebral palsy. The benefit of these systems may extend beyond energy expenditure, as the visual feedback gained from on screen body positioning with AVGs such as Xbox Kinect™ could facilitate proprioception and motor control learning that may not be gained from traditional exercise alone.

This study is limited by a small sample size with a narrow range in ages, therefore making the results most applicable to college-aged subjects. While game comparisons included both upper and lower body activities, investigations into more of the ever-growing selection of popular AVGs is warranted. Some limitations in data collection may have occurred due to the use of the metabolic cart and its associated tubing. This could have prevented the subjects from moving as freely or as naturally as they would while playing without it. There is additionally the potential that subjects' playing behavior was affected simply by knowing they were being observed during game play (1). How this would affect their values is unknown. Finally, this study did not control for subject gaming experience. Sell et al. (18), reported that players with greater playing experience could achieve higher exercise intensities than less experienced players. It was observed that more experienced players could play at a higher level of difficulty in a given game. While our study required all subjects play games at the same level, gaming experience may have still affected the physiological responses to playing.

Future investigations should investigate the physiological responses to playing AVGs in a wider range of ages and variety of games. Additionally, investigations into what exact component or task during game play elicited the highest intensities are needed. Maximizing this part of game play could result in higher average exercise intensities and therefore increase the potential of AVGs as an alternative means to satisfy daily exercise recommendations.

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