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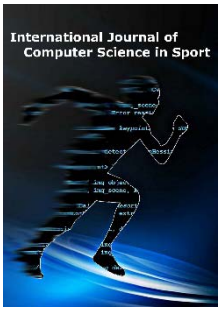

Comparisons of Heart Rate and Energy Expenditure During Exergaming in College-age Adults

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Abstract

The purpose of this study was twofold: 1) to discover the differences in degree of energy expenditure (EE) during Just Dance 2015 using Xbox 360 Kinect, Wii-U, PS3 Move, and Control YouTube video; and 2) to uncover whether or not exergaming could elicit moderate to vigorous levels of intensity (≥ 40% Heart Rate Reserve (HRR)) based on heart rate average (HR_{avg}) measurements. Twenty-five healthy college-aged students participated in this study. Data collection was comprised of baseline testing, a 30 second familiarization period with each gaming console, and a gaming session. Participants danced to the song "Love Me Again" on a Just Dance 2015 program on Xbox 360 Kinect, Wii-U, PS3 Move, and a control YouTube. EE and HRR were calculated using FT4 Polar Heart Rate Monitor. One-way repeated measures ANOVA indicated no significant differences in energy expenditure across the consoles, $F(2.74, 65.86)=0.65$, $p=.570$. The paired samples t-test indicated the HR_{avg} for the Xbox 360 Kinect (117±18 bpm) was significantly greater than the HR_{avg} for the Control (112±16 bpm), $t(24)=3.03$, $p=.006$. About a third (28%-36%) of participants met moderate levels of intensity while exergaming. Dancing on all three major gaming consoles and YouTube video increase energy expenditures and can be used as an alternative form of exercise with the ability to achieve moderate levels of intensity.

KEYWORDS: EXERGAMES, ENERGY EXPENDITURE, HR

Introduction

With an estimated 54% of college-aged students not meeting the guidelines for Moderate to Vigorous Physical Activity [MVPA; ≥40% heart rate reserve (HRR)],(American College Health Association, 2015; Crouter, Albright, & Bassett, 2004) physical inactivity is one of major behavioral concerns for their health. Entertainment Software Association (2016) stated that 63% of U.S. households have at least one person who plays video games regularly (3 hours or more per week), which contribute to the sedentary behaviors. The increases seen in screen time has been criticized for the obesity epidemic in our society (Lanningham-Foster et al., 2006). With inactivity prevalent in the U.S., there is a need to combat this trend (Thompson, 2014) by seeking alternatives to simply "being physically active" through outdoor activities or home-base activities. Any possible interventions that could slow or reverse this pattern are of crucial importance.

Exergaming Consoles

Exergaming, playing video games that require players to be physically active (Oh & Yang, 2010), opened up new avenues for increasing energy expenditure (EE). Little research has been conducted on the comparison of physiological benefits from the same game across the three major gaming consoles (PS3, Wii-U, and Xbox 360).

The Nintendo Wii-U (Wii-U, Nintendo Co., Ltd., Redmond, WA) utilizes a handheld wireless controller containing an accelerometer. This accelerometer detects the motion of the gamer in three axes then registers the data collected through infrared beams on the sensor bar (Marks et al., 2015). Success or failure of the gaming system relies on the recognition of the wireless controller and accelerometer by the sensor bar. This gaming system only requires using one arm to hold the controller.

The Xbox 360 and Kinect (Xbox 360 Kinect, Microsoft, Redmond, WA) create an exergaming system that recognizes 20 joints on a player's body. The Kinect also utilizes a 3-dimensional camera complete with microchip for tracking best situated eight feet away from the player. The device allows for movement to be recorded in an angular field horizontally and vertically on top of a pivot tilt (Parry et al., 2014). Due to the number of body joints recognized and differences in player's sizes, foot movements are often overestimated while hand markers are often underestimated up to 30%. However, when the body is viewed as a whole, movement patterns are gathered with higher accuracy (Van Diest et al., 2014). Higher accuracy is obtained because overestimations in the upper body movements and lower body movements are counterbalanced.

The PlayStation 3 Move (PlayStation 3 Move, Sony, San Mateo, CA) uses a universal serial bus camera to track 3-dimensional movement from a controller with a lighted ball on top and internal sensors for tracking movement. Movement is collected through the use of a 3-axis gyroscope and accelerometer and terrestrial magnetic field sensor best set five to seven feet away from the player (Parry et al., 2014). Like the Nintendo Wii-U, the PS3 Move utilizes accelerometers and requires only one hand for play.

Based on a meta-analysis and a system review conducted by Peng, Lin, and Crouse (2011) and Sween et al. (2014), respectively, only five studies have examined the effectiveness of exergaming on EE among adult population. Siegel et al. (2009) demonstrated that average EE during exergaming with three different active videogames in college students increased significantly as compared to resting values of EE. Furthermore, Scheer et al. (2014) compared EE, HR, and oxygen consumption across three exergaming consoles using different exergames among young adults but found no differences. In contrast, Marks et al. (2015) demonstrated

that the Xbox 360 Kinect elicited increased EE than did the Wii-U when playing the same games (i.e., Boxing and Just Dance 2). This may have been due to Xbox 360 Kinect requiring whole body movements vs. Wii-U only requiring arm movements. To the best of our knowledge, no studies have compared the amount of EE and the intensity of exercise in college students across all three consoles using the same dance simulation exergame.

The purpose of this study, therefore, was twofold: 1) to discover the differences in degree of EE during dance simulation exergame (i.e., Just Dance 2015) using Wii-U, PS3 Motion and Xbox 360 Kinect; and 2) to uncover whether or not exergaming could elicit moderate intensity physical activity.

Methods

Participants

After approved by the Institutional Review Board, 25 college students (male n=6 & female n=19) were recruited to participate in the study. Recruitment occurred through the use of classroom presentations, word of mouth and emails to various majors students from a Midwest college in the United States. After initial interest was expressed by 80 possible participants, these individuals were sent a more in-depth email with cover letter, consent form and detailing sign-up procedure via an online calendar. Twenty-five subjects followed through and signed-up for the meeting with the investigators. In order to participate in our study, subjects had to be apparently healthy, college-aged students.

At the beginning of the meeting, researchers explained the cover letter and informed consent to each participant, emphasizing time commitment, confidentiality, potential benefits and risks, and IRB resources. After the consent, the participant completed the seven physical activity readiness questionnaire (PAR-Q) to determine eligibility. Through a series of yes or no questions, the form identified those persons who may have had an underlying health condition. If the subject marked "yes" for any of the questions regarding heart health, they could not participate in the study unless cleared by a medical professional. On the day of data collection meeting, each participant's height, weight, and resting HR (HR_{rest}) were recorded to obtain participant characteristics (See Table 1). Information gathered was also used to aid in the accuracy of calculating HR and EE. The participant's height and weight were measured using the DETECTO Physician's Scale (Model 439, DETECTO Scale Company, Webb City, MO) with their shoes, jewelry, and excess clothing removed.

Study Procedure

On the day of data collection, participants arrived at the Human Performance Laboratory dressed in workout apparel and having refrained from drinking coffee or working out in the previous 24 hours. Refraining from these actions allowed investigators to limit fluctuations in HR_{rest}, which was used to determine exercise intensity based on HRR.

Average and maximum HR (HR_{avg} and HR_{max}, respectively) and EE during gameplay were measured through the use of the FT4 Polar Heart Rate Monitor (FT4 Polar Heart Rate Monitor, Polar Electro Inc., Lake Success, NY). Because the FT4 Polar Heart Rate Monitor utilizes the same regression equations for EE as the S410 model, it was used as a reliable tool for measuring HR (Crouter et al., 2004). Upon completion of the song, the participant's HR (average and maximum per session) and EE were recorded. Age-predicted HR_{max} was calculated using 208-(.7*age) (Tanaka, Monahan, & Seals, 2001). HRR was calculated by taking the age-predicted HR_{max} minus HR_{rest}, which was measured via palpation of the radial artery at baseline testing. Calculated HRR for each participant was multiplied by .40 to

determine individual's moderate intensity of exercise during each exergaming session (American College of Sports Medicine, 2014). At the end of each minute of exercise, HR obtained from FT4 HR monitor was recorded, which were then used to calculate HR_{avg} (i.e., sum of four HR values divided by 4) for each song. Determination of whether or not each participant reached 40% HRR (i.e., moderate intensity) during each gaming exercise was based each participant's HR_{avg}. Because the Physical Activity Guidelines for Americans (2008) recommends that aerobic activity be accumulated in at least a 10-minute bout, HR_{avg} is more appropriate to be used to determine the intensity of exercise rather than a single HR measurement.

Table 1. Participant Characteristics[a]

Characteristics	**Males (n = 6)**	**Females (n = 19)**
Age (years)	21.67 ± 0.52	20.84 ± 1.74
Height (inches)	70.83 ± 2.27	66.00 ± 2.32
Weight (lbs)	174.17 ± 8.11	147.84 ± 20.13
HR_{rest} (bpm)	69.33 ± 12.42	71.63 ± 8.25

Abbreviations: HR_{rest}, resting heart rate; bpm, beats per minute
[a]Data are reported in means ± standard deviation.

The test administrator demonstrated the proper way to wear the Heart Rate transmitter (under the clothes in line with xiphoid process) before the participant put on this equipment. The administrator programmed the participant's data (height, weight, gender, date of birth) into the FT4 Polar Heart Rate Monitor watch (S410 Polar Heart Rate Monitor, Polar Electro Inc., Lake Success, NY) worn on the right wrist. After sitting for five minutes, the participant's resting HR from the watch was recorded. During this time, subjects completed an experience questionnaire on their exergaming history.

The order of gameplay (control YouTube Video, Wii-U, PS3 Move, and Xbox 360 Kinect) was randomized for each participant (See Table 2). The participant was familiarized with each gaming console for 30 seconds using the song "Happy" by Pharrell Williams. Each console familiarization happened just prior to playing each console. For example, participants played Xbox 360 for 30 seconds prior to data collection for Xbox 360. Researchers found out that research participants were familiar with exergaming consoles when we asked about their exergaming history. To minimize their physical movement prior to data collection and save participants' time, researchers used the 30 seconds for the familiarization for each console. Once familiarization on a console was completed, and the participant's HR returned to resting level, testing on the respective console was executed with the song "Love Me Again" by John Newman. All devices were zeroed before testing began and the subject was instructed to refrain from all movement at the end of the song. The HR monitor was started right before the song began to play. Upon completion of the song, the participant's Ratings of Perceived Exertion (RPE, used average on the modified Borg Scale) and HR (average and maximum per session) were recorded. Between subsequent gaming sessions, the subject rested for five minutes to allow for HR to return to resting levels. This amount

of time was chosen based off of an existing exergaming study (Marks et al., 2015) which determined a length of 5 minutes was adequate to allow for heart rates to decrease to resting levels. After each session, the participant's RPE and HR were recorded again.

Table 2. Participants Order of Dance (N=25)

Participant	Order [a]	Participant	Order
1	1, 4, 2, 3	14	2, 1, 4, 3
2	2, 4, 3, 1	15	3, 4, 1, 2
3	4, 3, 1, 2	16	1, 3, 2, 4
4	3, 4, 2, 1	17	4, 2, 1, 3
5	4, 3, 2, 1	18	3, 1, 2, 4
6	3, 4, 1, 2	19	1, 4, 3, 2
7	2, 4, 1, 3	20	2, 1, 3, 4
8	1, 4, 2, 3	21	3, 2, 1, 4
9	1, 3, 4, 2	22	2, 1, 4, 3
10	2, 3, 4, 1	23	4, 1, 2, 3
11	3, 2, 4, 1	24	3, 1, 4, 2
12	1, 4, 3, 2	25	2, 3, 1, 4
13	1, 2, 3, 4		

[a] 1=Control YouTube Video, 2= Xbox 360 Kinect, 3= Wii-U, & 4= PS3 Move

Gaming Session

The entire study lasted a total of 75 minutes in length of one session for each participant. Each gaming console was set up in a different private racquetball room at the University, and all testing sessions took place in these rooms. Participants were tested individually to avoid potential mental distress (e.g., embarrassment) from dancing in front of others. To ensure valid assessment, all gaming consoles and remotes were charged prior to each session. The song selected for testing, "Love Me Again" by John Newman, was selected for following reasons: gender neutrality, difficulty level as well as length. The song itself was under four minutes long and did not have confusing background animations that could potentially distract participants. The control video in the study was a YouTube video of a dancer completing the same choreography for the same song "Love Me Again" as in Just Dance 2015 which lasted for approximately 4 minutes. The control video was not interactive, meaning that no feedback was provided to the participant.

Data Analysis

This study is a static group comparison with four independent groups: the Wii-U, Xbox 360 Kinect, PS3 Move, and a control YouTube video via computer. Participants' step counts, HR, EE and RPE were collected and analyzed for each console. To assess differences in dependent variables across the consoles, a one-way repeated measure ANOVA analysis was employed at an alpha level of .05 using the SPSS version 19.0 software.

Results

Twenty-five participants completed the gaming sessions using the control YouTube video, Kinect, Wii-U and PS3 Move. No participants dropped out of the study. The mean age of male participants was 21.67 ± 0.52 years old and the mean age of female participants was 20.84 ± 1.74 years old.

Physiological Responses

See Table 2 for descriptive statistics for HR_{avg} and EE across for gaming exercises. Using an alpha level of .05, a one-way repeated measures ANOVA indicated no significant differences in energy expenditure across the consoles, $F(2.74, 65.86)=0.65$, $p=.570$. Another one-way repeated measures ANOVA indicated a significant difference in HR_{avg} across the consoles, $F(3.00, 72.00)=3.73$, $p=.015$. To determine where this significant difference occurred, a paired sample t-test was used to evaluate HR_{avg} of the participants. Using a familywise alpha level of .05 the paired samples t-test indicated the HR_{avg} for the Xbox 360 Kinect (117±18 bpm) was significantly greater than the HR_{avg} for the control (112±16 bpm), $t(24)=3.03$, $p=.006$.

Table 3. Energy Expenditure and Heart Rate Average (N=25) [a]

Console	Energy Expenditure (kcal/min)	Heart Rate Average (beats/min)
Control Youtube Video	20.56 ± 9.39	111.96 ± 15.70
Xbox 360 Kinect	21.76 ± 10.14	116.60 ± 18.49
Wii-U	20.44 ± 8.08	114.24 ± 16.91
PS3 Move	20.76 ± 8.95	114.00 ± 15.34

[a]Data are reported in means ± standard deviation.

Table 4. Paired Samples t-test of Heart Rate Average (N=25)

Console Combination	Mean	SD	t	*p*
Kinect vs. Control	4.64	7.65	3.03	.006*
Wii-U vs. Control	2.28	7.67	1.49	.150
PS3 Move vs. Control	2.04	6.13	1.66	.109
Kinect vs. Wii-U	2.36	6.54	1.80	.084
Kinect vs. PS3 Move	2.60	6.85	1.90	.070
Wii-U vs. PS3 Move	2.40	6.75	0.18	.860

Abbreviations: SD, standard deviation; *p<0.05.

Moderate Exercise Intensity

About a third (28%-36%) of participants met moderate levels of intensity while exergaming on the Wii-U, Xbox 360 Kinect, and PS3 Move. After examining individuals' HR_{avg}, 26.3% (n=5) of female participants and 16.7% (n=1) of male participants reached moderate levels of

intensity while playing the Control. When playing the Xbox 360 Kinect, 31.6% (*n*=6) of female participants and 33.3% (*n*=2) of male participants, respectively, elicited a HR_{avg}≥40% (i.e., moderate levels of exercise intensity) of their HRR. In gameplay with the Wii-U console, 26.3% (*n*=5) and 33.3% (*n*=2) of females and males, respectively, reached a HR_{avg} showing moderate levels of exercise intensity. While playing the PS3-Move, 26.3% (*n*=5) and 66.7% (*n*=4) of females and males, respectively, reached moderate levels of exercise intensity (See Table 5).

Table 5. Percentage and Number of Participants Meeting Moderate Exercise Intensity (≥40% HRR)

	Total (N=25)		**Female (n=19)**		**Male (n=6)**	
	%	n	%	n	%	n
Control	24.0	6	26.3	5	16.7	1
Xbox 360 Kinect	32.0	8	31.6	6	33.3	2
Wii-U	28.0	7	26.3	5	33.3	2
PS3-Move	36.0	9	26.3	5	66.7	4

Abbreviation: HRR, heart rate reserve calculated using age-predicted $HR_{max(}$208-(.7*age)-HR_{rest} (Tanaka, Monahan, & Seals, 2001)

Discussion

The aim of this study was to examine the differences in the amount of EE during Just Dance 2015 across the three consoles (i.e., Wii-U, PS3 Motion and Xbox 360 Kinect); and to explore the possibility of eliciting moderate intensity physical activity by playing the dance simulation exergame in college students.

The primary findings of this study indicated that there were no significant differences in EE while playing the control, Xbox 360 Kinect, Wii-U or PS3 Move. A significant difference was found with respect to HR_{avg}. While playing the Xbox 360 Kinect, participants elicited HR_{avg} that were significantly greater than the HR_{avg} elicited while playing the control video. Additionally, moderate intensity of exercise using ACSM criterion (40-59% HRR) could be achieved while playing all four gaming conditions.

Participants in this study were college-aged individuals with the average age of males being 21.67 ± 0.52 years old and females being 20.84 ± 1.74 years old. This sample was consistent with several other studies that also examined exergaming among college-aged students. (Marks et al., 2015; Scheer et al., 2014; Siegel et al., 2009) Though many studies focus on college-aged individuals, the gender distribution of such studies vary. This study was comprised of 19 female participants and 6 male participants, which was a fairly uneven distribution. Other studies looking at this same population had more equal distributions of male and female participants. (Marks et al., 2015; Scheer et al., 2014)

Data for EE collected across all four consoles indicated that the subjects burned an average of 20.56±9.39 kcals while playing the control video, 21.76±10.14 kcals while playing the Xbox 360 Kinect, 20.44±8.08 kcals while playing the Wii-U, and 20.7±8.95 kcals while playing the PS3 Move. No significant differences were found regarding EE across the gaming conditions. Our results were supported by research conducted by Scheer et al. (2014) which also found that there were no differences in EE when playing similar exergames (i.e., *Wii Boxing, Kinect*

Boxing, and Move Gladiatorial Combat). Although, Marks et al. (2015) found that EE was significantly greater while playing the Xbox 360 Kinect (*Boxing and Just Dance 2*) when compared with the Wii (*Boxing and Just Dance 2*), based on the results of the current study, exercise engaged while playing games on any of the three exergaming consoles can contribute to a similar energy expenditure value. Therefore, college-students can freely choose any available console and YouTube video to facilitate engagement of home-based exercise.

Examination on HR levels achieved while playing the Xbox 360 Kinect met ACSM criterion for moderate intensity physical activity (40-59% HRR) was partially supported by our findings. HR_{avg} for the Control was 111.96±15.70 beats per minute (bpm) while the Xbox 360 Kinect was 117±18 bpm. The Wii-U elicited HR averages of 114±17 bpm while the PS3 Move elicited HR averages of 114±15 bpm. HR_{avg} were significantly different compared across all four consoles. More specifically, the Xbox 360 Kinect elicited HR_{avg} that were significantly higher when compared to the HR_{avg} of the Control. Findings were consistent with results found by Marks et al. (2015) and Siegel et al. (2009) which found that during game play, HR differed between gaming conditions. Conversely, this study's results contradicted Scheer et al. (2014) which did not find any significant differences in HR between various consoles.

Research has indicated that many physiological benefits can be achieved by exercising at moderate levels of intensity. The purpose of this investigation was to see if exergaming could use to meet the threshold for moderate intensity levels for physical activity. Results show that in each of the gaming conditions moderate intensity levels could be reached. Out of all of the gaming conditions, the PS3 Move had the greatest number of participants, 36% of participants (n=9), achieving moderate intensity levels during game play. These findings are supported by Marks et al. (2015) who found that peak exercise intensities during exergaming met the threshold for moderate intensity physical activity; however, they found this intensity was not maintained over the entire duration of the testing session. This is of particular interest, because these studies together suggest that certain games are more effective at eliciting moderate intensity levels of physical activity than others. Another study by Siegel et al. (2009) also concluded that exergames could be used to meet exercise program requirements, particularly aerobic requirements. From this point of view, even if MVPA is not met, exergaming still provides participants with increased HR and potentially elevated caloric expenditure than sedentary gaming.

With respect to sex difference in the intensity of activity exerted by individuals while engaging in the dance movements using the four gaming consoles, the results of the present study illustrated that the percentages of female participants meeting the moderate levels of activity intensity, based on HR_{avg} values obtained from FT4, were fairly stable (range of 26.3-31.6%) across four consoles. While we acknowledge the limitation of having 6 male participants in the current study, it is of interest to observe the greater percentage of male participants' HR_{avg} exceeding the threshold for moderate intensity while gaming on the PS3-Move as compared to the other three (Wii-U, Xbox 360 Kinect, and Control YouTube). In the reporting of Kilpatrick and colleagues study (2005), motives for sport and exercise participation differed between male and female college students, such that, males were more motivated by performance factors including challenge, strength and endurance, competition, and social recognition as did females in all activity types (Kilpatrick et al., 2005). Combined with this notion of males being more inclined to exercise and participate in physical activity with a mindset of achieving ego-related goals (Kilpatrick et al., 2005), the interactive nature of the PS3-Move game console using not only the motion-sensitive hand-held controller but also a range of camera technology, which provides a real-time tactile and visual feedback to the game players pertaining to their movement patterns, may have motivated a greater proportion of male participants in our study to engage in increased physical exertion while gaming on PS3-Move

than while gaming on other consoles that have difference interfaces (Martin & Wiemeyer, 2012). Subsequent research designed to obtain subjective feedback on the game flow (i.e., concentration, challenge skills, control, clear goals, feedback, immersion and social interaction) is deemed to provide better insight on the psychological aspect of exergaming.

One limitation of the present study was that EE was measured using indirect calorimetry. Direct calorimetry may have provided more accurate data collection. Another limitation was the small sample size recruited for this study which may not have made the results from this study applicable to a larger population. Because the current study was predominantly female, the results cannot necessarily be generalized to a larger male population. Furthermore, the population of this study was apparently healthy college-aged individuals as opposed to their sedentary peers.

One of the strengths of this study is that it is the first study to examine the physiological responses across the Xbox 360 Kinect, PS3 Move, and Wii-U using the same song in the same dance game. The study also was conducted over the span of one session, eliminating any potential fluctuations in participant characteristics (height, weight, HR_{rest}). In turn, this reduced many potential threats to the validity of this study such as experimental mortality, multiple treatment interference, etc.

The results from this study suggest that exergaming has the potential to meet moderate levels of intensity and can be used as an alternative mode of exercise. In relation to gaming consoles, this study found no significant differences between the Wii-U, PS3 Move, and Xbox 360 Kinect. However, HR_{avg} was higher during game play with the Xbox 360 Kinect compared to the control. This may suggest that exergaming offers a motivational component which may explain variations in data compared to the control. Specifically, video workouts that offer no movement feedback could be compared to fitness exergames which provide interactive feedback to determine if exergames will elicit higher physiological responses than fitness videos. In the future, the relationship between exergaming and motivation could be explored further.

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