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A Quantitative Comparison of Energy Expenditure Between Exergames and Physical Activity Recommendations

Dalton A. Newell
University of Southern Mississippi

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The University of Southern Mississippi

A Quantitative Comparison of Energy Expenditure
Between Exergames and Physical Activity Recommendations

by

Dalton Newell

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of the Requirements for the Degree of
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Approved by

Dr. Michael J. Webster
Associate Professor of Exercise Science

Dr. Trenton Gould, Director
School of Human Performance and Recreation

Dr. David R. Davies, Dean
Honors College

Abstract

The purpose of this study was to analyze the energy expenditure associated with two commercially available exergames (Dance Dance Revolution 2 (DDR2) and Wii Sports 1: Tennis) and evaluate whether or not this type of activity could be used as a means to obtain the recommended amount of physical activity. Thirty individuals (15 males, 15 females) participated in the study. Each participant attended 3 sessions: a 30-min familiarization session and 2, 45-min testing sessions. During each testing session, participants played one of the exergames for 30 min while continuously being measured for oxygen consumption (VO_2), respiratory exchange ratio (RER), and heart rate (HR), and at specific intervals being assessed for their rating of perceived exertion (RPE). All data were analyzed using the IBM SPSS Statistics 20 program for Windows. VO_2 , RER, HR, and RPE were analyzed using separate (time X game) factorial, repeated measures analyses of variance (ANOVA). Statistical significance was set at $p < 0.05$. The results indicated significant differences for both VO_2 and HR across time ($p < 0.001$), between groups ($p < 0.001$ and $p = 0.001$, respectively), and for game*time interaction ($p = 0.015$ and $p < 0.001$, respectively). There were no significant differences for RER over time ($p = 0.283$) or between games ($p = 0.526$). As expected, there was a significant rise in RPE over time ($p < 0.001$); however, there was no significant difference between groups ($p = 0.316$). DDR2 elicited a significantly higher ($p < 0.001$) total energy expenditure than Wii Sports 1: Tennis (DDR2 102.8 ± 32.3 , Wii Sports 1 Tennis: 68.3 ± 21.3 kcal). Relative VO_2 was converted to METs for each exergame, and DDR2 met the minimal criteria for moderate intensity physical activity (2.98 ± 0.76 METs).

Keywords: exercise, Nintendo Wii, VO_2 , HR, RPE

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CHAPTER I: Introduction

Physical inactivity, often referred to as a sedentary lifestyle, has become a recurring issue for youth and college students alike. The seriousness and impact of physical inactivity is often overlooked; however, the health risks that accompany such a lifestyle, including obesity, cardiovascular and metabolic diseases, cancer, and psychosocial problems, are far too great to underestimate (Tremblay, Colley, Saunders, Healy, & Owen, 2010). The “culprits” leading to a sedentary lifestyle are many and vary from excessive amounts of sleeping, video games, and/or watching television. Nonetheless, the one factor that unites all definitions is a severe lack of necessary physical activity. According to Warburton et al. (2007), “The steepest decline in physical activity occurs between high school and young adulthood.” Simply put, the gap between high school and young adulthood, college, is the period during which many preventable diseases begin to develop.

Physical activity and exercise are two terms that are often interchanged with one another; and while they are related, they are also distinctly different. Physical activity involves any energy expenditure that results from the movement of skeletal muscle, whereas exercise is planned, repetitive physical activity whose aim is to improve or maintain some aspect of physical fitness (Caspersen, Powell, & Christenson, 1985). Warburton et al. (2007) argue that reinforcing physical activity with seemingly sedentary behaviors serves as an effective means by which to improve health status and promote physical activity. This method may seem a bit counterintuitive; however, for someone caught in the slippery slope of a sedentary lifestyle, this may be an avenue towards recovery.

One such method of physical activity reinforcement that has surfaced over the past decade is a phenomenon known as exergaming, also known as active or interactive video gaming. The term active video games describes video games that integrate two previously separate ideas, video games and physical activity, by requiring players' body movements to interact with the gaming system (Peng, Lin, & Crouse, 2011). Due to the popularity of video games among school-aged children, adolescents, and young adults, the hope is that this form of intervention could be useful in battling physical inactivity and associated health complications in these populations.

The focus of this study was the analysis of two specific exergames, Dance Dance Revolution 2 (DDR2) and Wii Sports 1: Tennis, both supported by the Nintendo Wii video game console, a popular, leading brand in the exergaming industry. Specifically, this research was a quantitative analysis of the differences in energy expenditure of the participants playing the games as well as how playing a particular game compared to the recommendations for physical activity and energy expenditure provided by The American College of Sports Medicine (ACSM) (Pescatello, Arena, Riebe, & Thompson, 2014). The research subjects in this study were male and female college students between the ages of 18 and 30.

If exergames were found to result in significant energy expenditure in the sample population, they could have the potential to provide a new mode of exercise that meets the current physical activity guidelines for young adults. Therefore, as the video game industry grows, exergames could become an increasing interest to health professionals causing exergames to become a viable compromise for more active leisure-time activity.

CHAPTER II: Review of Literature

Sedentary behavior, defined by Tremblay et al. (2010) as behavior involving low energy expenditure (≤ 1.5 METS), has recently become of increasing importance due to its correlation to health-related issues. Most experts agree that sedentary behavior is a major contributor to the epidemics of obesity, type 2 diabetes, cardiovascular and metabolic diseases, hypertension, and various forms of cancer (Teychenne, Ball, & Salmon, 2010; Tremblay et al., 2010). Teychenne et al. (2010) suggest that sedentary behavior includes a variety of activities including television viewing, computer use, playing video games, and passive recreation such as listening to music. Partially due to the unfathomable technological advancements over the past few decades, children are now being introduced to television and video games at a much younger age, instilling in them the mindset that physical activity is a thing of the past. Research indicates that the average age at which children began to watch television in 1971 was 4 years; today, the average is only 5 months (Tremblay et al., 2010). According to Penko and Barkley (2010), “8-18-year-old children reportedly spend $1.1 \text{ h}\cdot\text{d}^{-1}$ playing video games and up to $6.1 \text{ h}\cdot\text{d}^{-1}$ of total screen use (television, computers, video games).”

Warburton et al. (2007) and Kraft, Russell, Bowman, Selsor, & Foster (2011) contend that the amount and level of physical activity drop significantly for most individuals between high school and young adulthood and that traditional physical activities are not perceived as enjoyable by this age group. Moreover, approximately one-fourth of ‘gamers’ (those who play video/computer games on a regular basis) are classified as young adults (Siegel, Haddock, Dubois, & Wilkin, 2009). Being that physical activity has been linked to the management and prevention of many of the

chronic diseases listed above, it is imperative that new methods for increasing physical activity in adults be examined (Mark, Rhodes, Warburton, & Bredin, 2008; Barkley & Penko, 2009).

According to Caspersen et al. (1985), “Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure.” On the other hand, physical activity that is planned and repetitive and whose goal is to improve or maintain some aspect of physical fitness is termed, exercise (Caspersen et al., 1985). Caspersen et al. (1985) also defines physical fitness as a “set of attributes that people have or achieve” with the idea of being physically fit defined as “the ability to carry out daily tasks with vigor and alertness, without undue fatigue and with ample energy to enjoy leisure-time pursuits and to meet unforeseen emergencies.” There are both health and sport-related components of physical fitness. The health-related components include cardiorespiratory endurance, muscular endurance, muscular strength, body composition, and flexibility, each of which must meet the outlined qualifications in order to classify an individual as being physically fit (Caspersen et al., 1985).

The Centers for Disease Control (CDC) recently indicated that > 30% of U.S. adults are either overweight or obese (Siegel et al., 2009). Furthermore, the CDC states that less than 50% of US adults participate in the recommended ≥ 30 minutes of moderate to vigorous physical activity (MVPA) at least five days per week (averaging an energy expenditure of 150-400 kcals per day) (Barkley & Penko, 2009; Pescatello et al., 2014; Siegel et al., 2009; Taylor, McCormick, Shawis, Impson, & Griffin, 2011). However, Barkley and Penko (2009) go on to state that U.S. adults reportedly spend in excess of 2 h·d⁻¹ watching television and using home computers, likely in place of time spent

engaging in physical activity.

Warburton et al. (2007) suggest that preceding behavior patterns are the best predictor of future behaviors and that altering previous activities such as those associated with a sedentary lifestyle could steer individuals away from the growing trend of declining physical activity from adolescence to young adulthood. Warburton et al. (2007) go on to suggest that using sedentary behavior as a means by which to reinforce physical activity is a simple, yet effective mode of increasing participation in physical activity and improving health status overall. Due to the popularity of video games among people of all ages, it makes sense that this reinforcement of physical activity with sedentary behavior could quite possibly come through the means of video games (Warburton et al., 2007). Likewise, Kraft et al. (2011) indicate that a contemporary development in the video gaming industry has been the recent rise in the popularity of interactive video games, also referred to as exergames. Exergames are “video games that incorporate physical activity into game play by requiring players’ body movements to interact with the game system” (Peng et al., 2011). Exergames are primarily designed to elevate heart rate and enhance aerobic activity thereby promoting an increase in energy expenditure. Accelerometers, gyroscopes, cameras, exercise equipment, pads and mats, and pressure sensors are all devices used to measure player input and provide feedback for analysis (Staiano & Calvert, 2011). Examples of popular exergaming systems include but are not limited to Xavix, Nintendo Wii, PlayStation, Xbox, and CatEye fitness equipment (Kraft et al., 2011; Taylor et al., 2011).

Siegel et al. (2009) suggest that while it is not possible to diminish the use of video games completely, exergames may provide enticement towards increasing physical

activity. Taylor et al. (2011) go on to suggest that the games available for exergaming systems provide both entertainment and distraction leading to a more enjoyable exercise session as well as an improved adherence to the recommendations for physical activity. Additional notions supporting the use of exergames as a means by which to meet the ACSM's recommendations for physical activity include the ability to exercise in the home, especially for those with low self-confidence, an attraction to video games as opposed to traditional forms of exercise, and the maximization of immediate gratification through the selection of enjoyable exercise activities (Kraft et al., 2011; Taylor et al., 2011). Furthermore, research suggests that incorporating the use of exergames into routine training may be an option for increasing the duration and quality of physical activity and aid in reversing inactivity (Kraft et al., 2011; Lanningham-Foster et al., 2006).

As mentioned earlier, exergaming applications are diverse in their types as well as in the gaming systems that support them. Having sold over 75 million units worldwide, the Wii is a gaming system that uses player movements to control onscreen action. The player is represented on the screen via an avatar called a Mii. Movement of the Mii is controlled by the player via one of three mechanisms or possibly a combination of the three: a remote, nunchuk, or balance board. A three-axis accelerometer is used in conjunction with the Wii remote in order for the Mii to portray the body movement of the player. The Wii console comes with a game package, Wii Sports, which includes tennis, baseball, bowling, boxing, and golf, each of which utilize the nunchuk and Wii remote in place of the equipment for the particular sport. An additional exergame that can be purchased for the Wii, Wii Fit, utilizes the balance board in order to assess strength,

fitness, and balance (Taylor et al., 2011).

Although originally released as a large-scale arcade game, Dance Dance Revolution (DDR) is now available on a variety of game consoles. Instead of a nunchuk or balance board, the controller is a floor mat that the player stands on. Responding to arrows that move across the screen in synchronization with a piece of music, the player moves his or her feet in a set pattern. Dance Dance Revolution provides onscreen feedback and calculates the accuracy of the player's performance (Taylor et al., 2011).

Three additional applications, the Eye Toy, PlayStation Move, and the Xbox Kinect, all possess similarities to, and compete with, the previously mentioned exergame applications. The Eye Toy is played on the PlayStation2 and uses a color video camera capable of recognizing player movements that allows for a similar onscreen replication for gameplay. PlayStation Move, similarly, uses the camera technology of the Eye Toy but also uses wands similar to the remotes used by the Wii to detect the player's movement. Much like the Wii, PlayStation Move also uses a three-axis linear accelerometer, but it also implements the use of a three-axis angular rate sensor. Also similar to the Eye Toy, the Xbox Kinect uses video technology and gesture recognition in order to create a controller-free game-play via the use of the player having his or her bodily movement recorded and projected (Taylor et al., 2011).

Although the exergame applications previously mentioned seem similar in their capabilities, Kraft et al. (2011) voice the concern that some applications seem to provide benefits that others do not, and this concern is what has driven a great deal of the research related to exergames. Recently 37 college students (20 males, 17 females) were assessed using the CatEye Gamebike (a bicycle interfaced with a video game), DDR, and a

traditional cycle ergometer. Participants completed an initial 30-min familiarization session and three testing sessions during which a different modality was used each time. Each testing session lasted 30 min. Heart rate (HR) and rate of perceived exertion (RPE) were the main variables assessed. The results indicated a significantly higher HR while using the CatEye Gamebike than while using DDR or the traditional cycle ergometer. Also, participants reported a much higher RPE while using the CatEye Gamebike and the traditional cycle ergometer than when using DDR (Kraft et al., 2011).

In a similar study, HR, oxygen consumption (VO_2), and RPE of 14 moderately inactive university-aged participants (7 males, 7 females) were assessed while the participants engaged in playing two interactive video games, SNAP and Wii Fit Step Aerobics. SNAP is an exergaming system that allows players to interact with the video game via the use of sensors attached to the players' limbs. Similar to the previously mentioned study, participants attended a 30-min familiarization session and played each exergame for 30 min. The results indicated that HR and RPE were both significantly higher for the SNAP application compared with the Wii Fit Step Aerobics (Whitehead, Johnston, Nixon, & Welch, 2010).

Another study evaluated 13 participants (6 males, 7 females) using three exergames: 3-Kick, Jackie Chan Studio Fitness Power Boxing, and Disney's Cars Piston Cup Race. 3-Kick is an arcade-style game that requires players to either kick or hit lighted pads. Jackie Chan Studio Fitness Power Boxing is an interactive video game that incorporates the use of boxing gloves containing sensors. Disney's Cars Piston Cup Race is an interactive video game involving the use of a stationary bike to propel the car in the video game. During the study, HR and energy expenditure (EE) were measured while the

participants played the three games for 30 min each. Due to the fact that this study was not a comparison of games, the results indicated simply that HR and EE increased significantly while participants were playing the exergames. This study, however, looked at gender in terms of its effects on EE, and the results indicated that EE was significantly higher for males than for females (Siegel et al., 2009).

Due to the novelty of this technology, research is only in the beginning phases of evaluating the effectiveness of exergames in promoting physical fitness and exercise adherence (Kraft et al., 2011). Additionally, the technological and gaming innovations are developing at a faster pace than the research investigating their efficacy. More specifically, it has yet to be determined whether or not exergames or other similar interventions would benefit populations such as the elderly that suffer from or are at a higher risk for limitations due to their musculoskeletal fitness levels. Similarly, because of the nature and extensiveness of this field of study, research is warranted that evaluates the use of exergames on a large scale such as in school systems and community centers (Warburton et al., 2007).

Although there are some minor discrepancies between studies, a great deal can be learned about which exergames elicit the greatest physiological responses. However, the largest gap and the greatest discrepancy in the literature is whether or not exergames can and/or should be used as a substitutionary means for engaging in the recommended amount of physical activity provided by the ACSM. Consequently, the purpose of this study was to analyze the energy expenditure associated with exergames (specifically DDR2 and Wii Sports 1: Tennis) and evaluate whether or not this type of activity could be used as a means to obtain the recommended amount of physical activity.

CHAPTER III: Methods

Participants:

Thirty (15 males, 15 females) apparently healthy university students representing a diverse population volunteered to participate in the study and provided written informed consent. Participant descriptive data were as follows: Age: Males 20.9 ± 1.9 , Females 20.5 ± 1.4 yrs.; Height: Males 1.76 ± 0.06 , Females 1.66 ± 0.05 m; Mass: Males 79.1 ± 22.1 , Females 61.3 ± 8.0 kg. Combined data indicated Age: 20.7 ± 1.6 yrs.; Height: 1.71 ± 0.07 m; Mass: 70.2 ± 18.6 kg. All experimental procedures were approved by The University Institutional Review Board for the use of human subjects in research and conformed to the ethical consideration of the Declaration of Helsinki.

Each participant attended three sessions. The first session was a familiarization session that lasted approximately 30 min. During this session participants were introduced to the testing equipment and study protocol and then practiced playing the specific exergames that were to be used during the subsequent testing sessions. The familiarization session also served as a time where the participants could ask questions about the testing protocol, expectations, risks, and time commitments required for participation in the study.

Sessions two and three were separated by at least 2-d, but no more than 7-d. These two sessions involved participants playing Dance Dance Revolution 2 (DDR2) and Wii Sports 1: Tennis on the Wii in a randomized, counterbalanced fashion. Of the 30 participants, 16 played DDR2 during their first session while the remaining 14 played Wii Sports 1: Tennis. During each session, participants played one of the exergames for 30 minutes while continuously being measured for oxygen consumption (VO_2),

respiratory exchange ratio (RER), and heart rate (HR), and at specific intervals being assessed for their rating of perceived exertion (RPE). The 30 min of game play included pauses between levels on the gaming system as well as any other unavoidable interruptions caused by the gaming system or external factors. However, each of these game-related interruptions and changing of levels was standardized and equal for each participant. Since the participants underwent a familiarization session, delays related to game playing inexperience were minimized.

Experimental Procedures:

During all game play, the fractional concentrations and the volumes of respiratory gases, oxygen (VO_2) and carbon dioxide (VCO_2), were determined continuously via open circuit spirometry (Viasis Vmax Encore metabolic system) using a standard facemask apparatus. Every three minutes, 30-s averages were used to determine the individuals VO_2 , respiratory exchange ratio (RER), and calculated energy expenditure (EE). Heart rate (HR) was determined by telemetry via a Polar heart rate monitor at rest and every 3-min, and RPE (Borg 6-20 scale) was recorded at rest and after every 6-min of exercise.

Statistical Analysis:

All data were analyzed using the IBM SPSS Statistics 20 program for Windows. Oxygen uptake, RER, HR, and RPE were analyzed using separate (time X game) factorial, repeated measures analyses of variance (ANOVA). Further analysis of the significant main effects was analyzed using separate univariate ANOVA. Bonferonni's post hoc procedure was utilized to minimize alpha inflation with the repeated measures procedure. Statistical significance was set at $p < 0.05$. The difference in 30-min EE during each exergame was analyzed using a student t-test and was also compared to the

American College of Sports Medicine (ACSM) recommendations for exercise intensity and energy expenditure (Pescatello et al., 2014).

CHAPTER IV: Results

Mean VO_2 over the course of the 30-min sessions are presented in Figure 1.

Univariate analysis revealed that VO_2 was significantly increased ($p < 0.001$) from rest to exercise ($+0.22 \pm 0.17 \text{ L}\cdot\text{min}^{-1}$) for both exergames combined. VO_2 was significantly higher ($p < 0.001$) for DDR2 ($0.70 \pm 0.27 \text{ L}\cdot\text{min}^{-1}$) than Wii Sports 1: Tennis ($0.46 \pm 0.17 \text{ L}\cdot\text{min}^{-1}$) over the course of the 30-min sessions. VO_2 from rest to exercise was increased greater ($p = 0.015$) for DDR2 ($+0.32 \pm 0.15 \text{ L}\cdot\text{min}^{-1}$) than for Wii Sports 1: Tennis ($+0.12 \pm 0.13 \text{ L}\cdot\text{min}^{-1}$).

Heart rate over the course of the 30-min sessions is presented in Figure 2.

Univariate analysis revealed that HR was significantly increased ($p < 0.001$) from rest to exercise ($+13 \pm 10 \text{ b}\cdot\text{min}^{-1}$) for both exergames combined. During exercise, HR was significantly higher ($p = 0.001$) for DDR2 ($114 \pm 15 \text{ b}\cdot\text{min}^{-1}$) than for Wii Sports 1: Tennis ($101 \pm 17 \text{ b}\cdot\text{min}^{-1}$) over the course of the 30-min sessions. Additionally, HR was significantly increased ($p < 0.001$) more rest to exercise for DDR2 ($+18 \pm 8 \text{ b}\cdot\text{min}^{-1}$) than for Wii Sports 1: Tennis ($+9 \pm 11 \text{ b}\cdot\text{min}^{-1}$).

Respiratory Exchange Ratio over the course of the 30-min sessions is presented in Figure 3. Univariate analysis revealed that there were no significant differences in RER over time ($p = 0.283$) or between DDR2 and Wii Sports 1: Tennis ($p = 0.526$).

Ratings of Perceived Exertion over the course of the 30-min sessions are presented in Figure 4. As expected, univariate analysis revealed that there was a significant rise ($p < 0.001$) in RPE over the course of the 30-min session. However, there was no significant between group differences ($p = 0.526$).

Energy Expenditure (Fig. 5) over the course of the 30-min sessions indicated that

DDR2 elicited a significantly greater ($p < 0.001$) energy expenditure than Wii Sports 1: Tennis (DDR2 102.8 ± 32.3 , Wii Sports 1: Tennis 68.3 ± 21.3 kcal). Mean METs over the course of the 30-min sessions (Fig. 6) was significantly higher ($p < 0.001$) in DDR2 than Wii Sports 1: Tennis (DDR2 2.98 ± 0.76 , Wii Sports 1: Tennis 1.99 ± 0.63 METs).

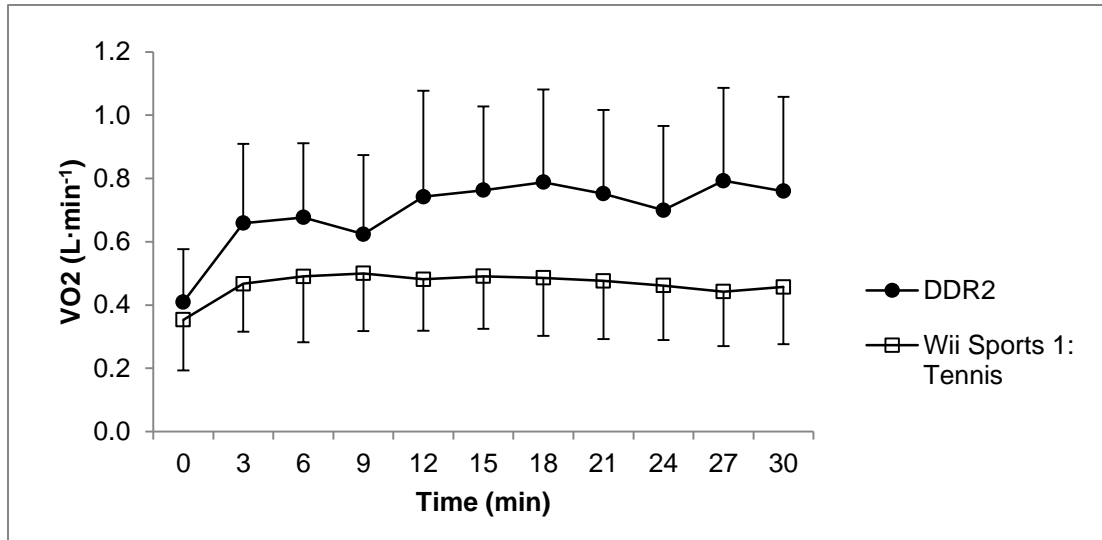


Figure 1. VO_2 ($L \cdot \text{min}^{-1}$) while playing Dance Dance Revolution 2 (DDR2) and Wii Sports 1: Tennis. Data presented are mean \pm SD. There were significant differences for time ($p < 0.001$), between groups ($p < 0.001$), and for game*time interaction ($p = 0.015$).

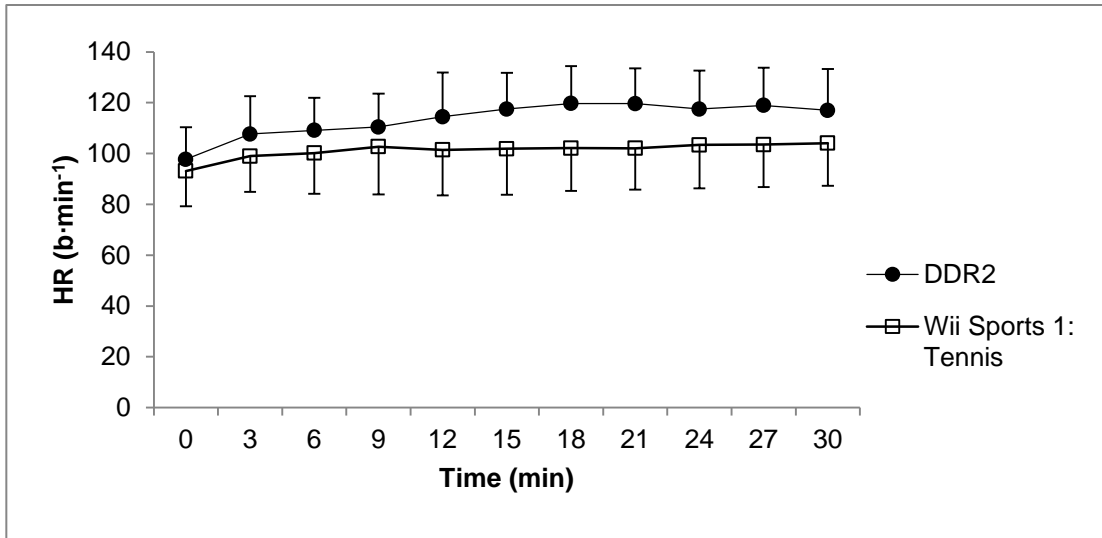


Figure 2. HR ($b \cdot \text{min}^{-1}$) while playing *Dance Dance Revolution 2 (DDR2)* and *Wii Sports 1: Tennis*. Data presented are mean \pm SD. There were significant differences for time ($p < 0.001$), between groups ($p = 0.001$), and for game*time interaction ($p < 0.001$).

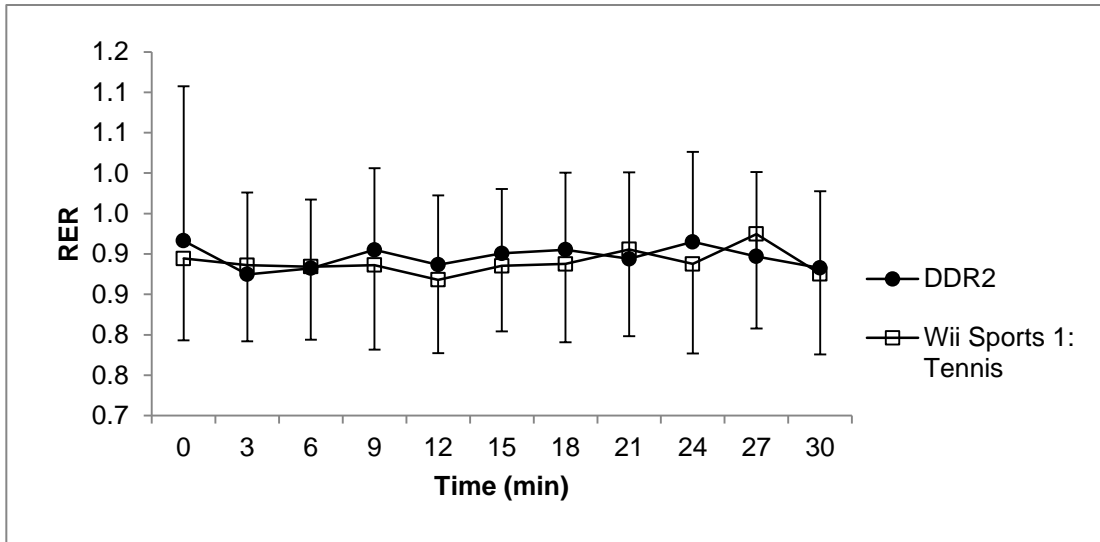


Figure 3. RER while playing Dance Dance Revolution 2 (DDR2) and Wii Sports 1: Tennis. Data presented are means \pm SDs. There were no significant differences over time ($p = 0.283$) or between games ($p = 0.526$).

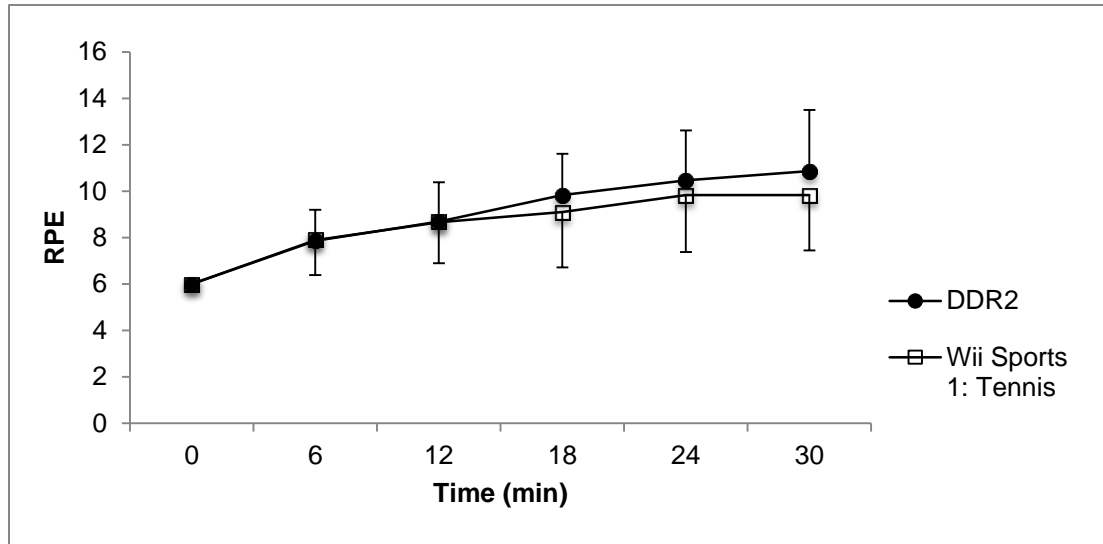


Figure 4. RPE while playing Dance Dance Revolution 2 (DDR2) and Wii Sports 1: Tennis. Data presented are mean \pm SD. There was a significant rise over time ($p < 0.001$); however, there was no significant difference between groups ($p = 0.316$).

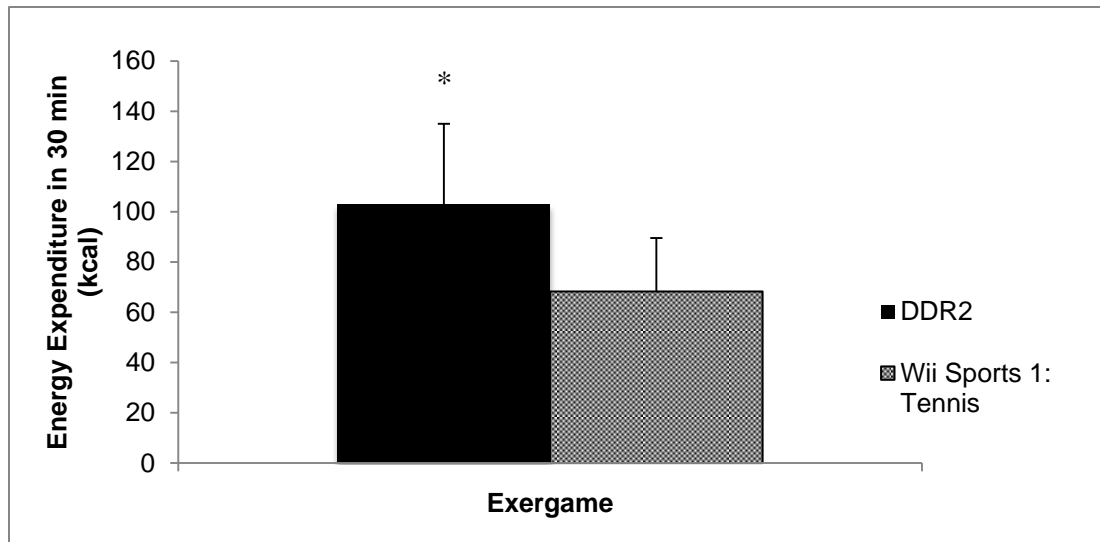


Figure 5. EE while playing Dance Dance Revolution 2 (DDR2) and Wii Sports 1: Tennis. Data presented are mean \pm SD. There was a significant difference between groups ($p < 0.001$). *Significant difference between groups.

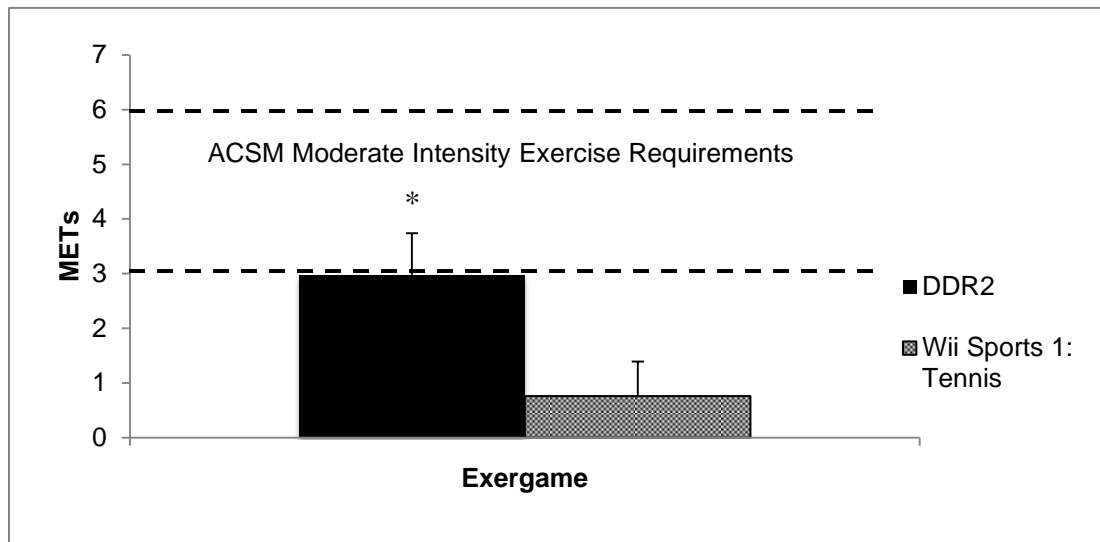


Figure 6. METs while playing Dance Dance Revolution 2 (DDR2) and Wii Sports 1: Tennis. Data presented are mean \pm SD. There was a significant difference between groups ($p < 0.001$). *Significant difference between groups.

CHAPTER V: Discussion/Conclusions

The primary goal of the current study was to determine whether or not university students would expend an adequate amount of energy to meet the ACSM's recommended intensity for physical activity while they played two different exergames, Dance Dance Revolution 2 (DDR2) and Wii Sports 1: Tennis. Game play on DDR2 elicited the minimum intensity for physical activity; however, 30-min of play did not achieve the minimum daily recommended EE. Game play using Wii Sports 1: Tennis; did not meet the minimum recommendations for either exercise intensity or EE.

Energy expenditure during DDR2 play ~33.5% greater than when playing Wii Sports 1: Tennis; however, neither met the recommended daily exercise EE of 150-400 kcal. Exercise intensity, estimated using METs, indicated that DDR2 meets the minimal criteria for moderate intensity physical activity (2.98 ± 0.76 METs); however, the exercise intensity associated with playing Wii Sports 1: Tennis only meets the criteria for low-intensity exercise (1.99 ± 0.63 METs). This, however, does not discount the fact that DDR2 and Wii Sports 1: Tennis can be used as avenues for physical activity; it simply means they are inefficient.

Given that ~3.4 kcal is expended each minute while playing DDR2, it would take approximately 43.8 min to meet the minimum recommended energy expenditure for a bout of physical activity. Likewise, the approximate 2.3 kcal expended each minute while playing Wii Sports 1: Tennis, would require ~65.9 min to meet the minimum recommended energy expenditure for a bout of physical activity. This deems both DDR2 and Wii Sports 1: Tennis inefficient in terms of energy expenditure. Comparable activities such as dancing and playing recreational tennis are much more efficient given

that it is estimated that they elicit MET levels of 3.0 and 5.0, respectively (Pescatello et al., 2014).

An additional area of interest that further supports that both DDR2 and Wii Sports 1: Tennis elicit a low physical activity intensity is the exercise HR. Based on the mean age of the participants, the estimated maximal heart rate for the participants is $199 \text{ b}\cdot\text{min}^{-1}$. The HR over the course of the 30-min sessions for DDR2 was $114 \pm 15 \text{ b}\cdot\text{min}^{-1}$ and for Wii Sports 1: Tennis was $101 \pm 17 \text{ b}\cdot\text{min}^{-1}$ which is 57% and 51% of their estimated maximal HR, respectively, indicating that playing these exergames demands only light physical activity (50 - 64% of maximal HR) (Pescatello et al, 2014).

In a similar study investigating the effects of exergaming and energy expenditure in college students, a trend in results was found. HR and EE increased significantly over time with the mean HR for the 30-min sessions being $163 \pm 11 \text{ b}\cdot\text{min}^{-1}$ and the mean total energy expenditure being $226.1 \pm 48.7 \text{ kcal}$. In the current study, however, the mean HR for the 30 participants over the course of the 30-min sessions was $107 \pm 15 \text{ b}\cdot\text{min}^{-1}$, while the mean EE was $102.8 \pm 32.3 \text{ kcal}$ and $68.3 \pm 21.3 \text{ kcal}$ for DDR2 and Wii Sports 1: Tennis, respectively. Based on these values and ACSM requirements, it is noted that on average, participants in the previous study were exercising at a vigorous physical activity intensity with their mean HR for the 30-min session being approximately 84% of their maximal HR, so although an increase in HR and EE occurred in both studies, the increase was significantly higher in the previous study (Pescatello et al., 2014; Siegel et al., 2009). Barkley and Penko (2009) compared exergame play to sedentary alternatives as well as treadmill walking and revealed a mean VO_2 during the 30-min exergame sessions of $15.40 \pm 4.50 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, which is ~50% higher than that reported in the present study

for DDR2 and ~225% greater than that reported for Wii Sports 1: Tennis.

Explanations for the differences in VO_2 , HR, and EE reported for the two exergames evaluated in the present study, as well as the differences with previous studies (Wii Sports 1: Boxing, 3-Kick, Jackie Chan Studio Fitness Power Boxing, and Disney's Cars Piston Cup Race) appears to be due to the type of activity required to perform the game. Those with a greater muscle mass or whole body activity have a greater metabolic demand. Several of the exergames evaluated in previous studies require the use of both arms and legs, whereas both of the exergames used in the present study required the use of either the arms or the legs, not both. In fact, participants could actually alter their movements while playing the exergames in the current study making it easier for them, yet still play the exergames effectively.

Although the results from the present study are in partial agreement with previous studies indicating that VO_2 , HR, and EE increase over time, the specific exergames played in this study did not elicit intensities that would warrant them to be considered as substitutionary for achieving the minimal levels of recommended physical activity (Pescatello et al., 2014). While the games evaluated in the present study elicited a relatively low metabolic demand, it is quite probable that these exergames could prove to be beneficial in rehabilitative and geriatric settings, where physical activity and motion are the focus, not metabolic demand.

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