DETERMINING INTENSITY LEVELS FOR SELECTED WII FIT ACTIVITIES IN COLLEGE AGED INDIVIDUALS

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ABSTRACT

Introduction: Physical activity is important to the proper growth, development, and overall health of an individual. Current physical activity trends show declines in activity level throughout aging. To counteract inactivity many physical activity interventions have been implemented in different age groups and yet very little change in activity level has been seen. The Nintendo Wii® offers a popular technological intervention tool with its movement oriented game play. The physiological costs and intensity of the Nintendo Wii Fit® game have not been thoroughly researched, yet the Wii is being used as a physical activity tool in many arenas. **Purpose:** The purpose of this study was to determine the intensity level of playing selected Nintendo Wii Fit® games using indirect calorimetry. Using the intensity information, it was determined if playing Wii Fit® (an exercise themed game) on the Nintendo Wii® video game console is an adequate activity for meeting the ACSM moderate physical activity guidelines threshold. **Participants:** Twenty-five participants, 5 males and 20 females, aged 22 ± 2 years (M ± SD) with little previous Wii experience (<10 times played) were recruited for this study. **Method:** Participants randomly completed two different Wii Fit activity sessions with two difficulty levels within the strength, endurance, and yoga categories. A resting metabolic rate and exercise $\dot{V}O_2$ were measured on each participant with a TrueMax 2400 metabolic cart. Oxygen consumption was then converted into metabolic equivalents to estimate activity intensity level. SPSS18.0 (Chicago, IL, USA) was used for statistical analysis. **Results:** Results indicated that $\dot{V}O_2$ of the selected Wii Fit activities was significantly higher than resting $\dot{V}O_2$ levels. For example, the least intense activity was the Yoga Warrior activity, which had a mean intensity of 2.30 ± 0.42 METs and was still significantly higher than resting $\dot{V}O_2$ levels, t (24) = 15.5, p < .001. The calculated MET values ranged from 3.28 ± 0.71 METs to 3.43 ± 0.60 METs for the strength activities, and ranged from 4.98 ± 1.22 METs to 5.73 ± 1.36 METs for the aerobic Basic Run exercises, indicating that the intensity levels of these activities met or exceeded the ACSM moderate intensity threshold of 3 METs. In contrast, the yoga exercises were significantly lower (from 2.30 ± 0.42 METs to 2.6749 ± .48 METs) than the recommended 3 METs, t (24) = -3.347, p= .003 for moderate intensity physical activity. Finally, the results showed that the medium difficulty level aerobic exercises (5.73 ± 1.36 METs) had significantly higher MET values than the easy aerobic exercises (4.98 ± 1.22 METs), t (24) = 5.00, p < .001. **Discussion:** The findings of this study illustrate the potential of the Nintendo Wii Fit® game to be an adequate physical activity tool. Furthermore, these findings will allow for the further advancement of exercise themed video games to become satisfactory replacements for traditional physical activities in future interventions.

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CHAPTER 1

INTRODUCTION

Physical activity participation is a vital component to the maintenance of overall health and the prevention of chronic long term diseases including: early death, coronary heart disease, stroke, high blood pressure, adverse blood lipid profile, type 2 diabetes, metabolic syndrome, colon cancer, breast cancer, and the prevention of weight gain [1-4]. During childhood, physical activity participation is essential to the proper growth of the body, the development of neural pathways, and in maintaining a healthy musculoskeletal system [5]. Habitual physical activity participation also elicits positive adaptations to the cardiovascular and muscular systems [3, 4]. The benefits of physical activity include fall prevention, better cognitive function and improved overall functional health [3]. Lastly, increased physical activity participation leads to higher levels of total daily energy expenditure which can help an individual with weight management when combined with reduced caloric intake.

Although the benefits of physical activity are well documented, awareness of physical activity recommendations (e.g., at least 10 minute bouts of physical activity; totaling 150 minutes per week of moderate aerobic physical activity or 75 minutes per week of vigorous aerobic physical activity; with the addition of strength training two times per week) and the benefits of physical activity among the U.S. population is low [6]. The American College of Sports Medicine (ACSM) and The Centers for Disease Control and Prevention (CDC) have developed general guidelines for physical activity that recommend a frequency of 3-5 days a week, a duration of 20-60 minutes and an intensity of 55-90% of max heart rate (MHR) [4, 7]. The United States Department of Health and Human Services (HHS) has developed age specific recommendations for adults which recommend at least 150 minutes of moderate intensity or 75 minutes of high-intensity aerobic activity a week to have extensive health benefits [3, 4]. Activity should be done in bouts that last a minimum of 10 minutes and total activity should be spread throughout the week [3, 4]. Strength training is another important component of physical activity for adults and should be of moderate to high intensity at least 2 days a week [3, 4].

More than a decade after the publication of the ACSM physical activity recommendations, many Americans are still living sedentary or less active lifestyles [8]. As mentioned previously, increased physical activity is associated with chronic disease prevention, whereas a lack of physical activity participation is associated with an increased risk of chronic disease [3, 9]. Obesity, for example, is a major health issue that is associated with an inadequate amount of physical activity. Other health conditions associated with physical inactivity include early death, coronary heart disease, stroke, high blood pressure, adverse blood lipid profile, type 2 diabetes, metabolic syndrome, colon cancer, breast cancer, and weight gain [1-4]. Therefore, to improve health and to decrease the risk of chronic diseases, it is important for individuals to increase physical activity participation adherence.

There are many factors that may contribute to sedentary lifestyles. One factor that has been researched thoroughly has been the role of technology on physical activity level [10]. Technological development and advancement could be playing a role in the increase in sedentary behavior among adults and children. As technology has advanced, decreases in physical activity are seen as citizens of "today's" generation are less active then previous generations [11-13]. Modifications to the education system for example led to changes in physical activity participation of children and adolescents in school settings due to a decreased emphasis on physical education curricula [5]. As these children mature into adulthood, the lack of physical education in the school systems may relate to the failure to develop physical activity patterns and habits. Furthermore, adults are being asked to be more productive at work, despite the fact that the average number of "at work" hours each week has not changed recently. This is leading to adults frequently bringing work home [14,15]. Adults may be finding it difficult to make time for physical activity when a large portion of the day is spent working two jobs or bringing work home. In addition, many of today's jobs are becoming white collar jobs (sitting in front of a computer or running a machine) that require little activity throughout the day. The high number of hours and low level of activity while at work leave very little time for adults to participate in physical activity.

Over the years, many intervention programs have been developed to increase physical activity participation; however, national physical activity trend data indicate that participation levels are decreasing rather than increasing among the US population [6, 8, 16]. The lack of success among U.S. adults in meeting the physical activity recommendations maybe related to how current physical activity interventions are designed. This does not mean that current interventions cannot be effective conduits for U.S. adults meeting the physical activity guidelines. The design, funding, and time commitment of many interventions limit them to smaller populations. Specifically the design component of many due to the fact that current physical activity interventions are structured in such a way that only a small percentage of a population is reached or these interventions are advertised in such a way that the whole population does not have access to appropriate information or the intervention itself [17]. Researchers have found that physical activity intervention research and development may not take into account the implementation of the intervention on a population wide scale [17].

The popularity of video game play is evident by the huge numbers of sales that are posted by companies every year. There are three main companies that are competing for video game sales: Microsoft (XBOX 360), Sony (Playstation 3) and Nintendo (Wii). The XBOX has been on the market in the U.S. the longest and has the second highest sales total. The Playstation 3 and the Wii both came out during the same fiscal quarter, yet the Nintendo Wii® has outsold the Playstation 3 and the XBOX during that time period. Currently there have been 22,932,838 Nintendo Wii® consoles sold in the United States as of April 18, 2009 [18]. There are many choices in video games as well with a variety of exercise themed games offered for the Nintendo Wii, including Wii Fit (Nintendo), Wii Fit Plus (Nintendo), EA Sport Active (Electronic Arts), and My Fitness Coach (Nintendo). Nintendo Wii Fit® was the first fitness game released and remains the most popular, selling 7,640,456 copies in the U.S. since its release [18].

Although, technology has been previously blamed for decreases in physical activity level, the continued development of technology has allowed for some incredible advancement to be made in many arenas. A majority of people in the U.S. now have access to technology through personally owned equipment, work equipment or public use equipment (public library). Longitudinal studies have found that the use of technology could theoretically provide greater access to physical activity interventions and may be the most efficient technique for promoting and implementing future interventions [11, 17]. Research has already begun examining the use of technology as a physical activity tool, for example the use of active video gaming systems such as Dance Dance Revolution and only recently the Nintendo Wii® has shown promising results [19-21].

Previously, active video game play was found only in arcades due to the large size of game consoles such as Dance Dance Revolution. Therefore, prior to the development of home based active video game consoles, access to these games was limited. The recent evolution of home video game consoles by Nintendo, revolutionized home video game play by incorporating player movement into video game control [22]. The improvement of video game consoles to home based systems has significantly increased the number of people who can now access this system. The Nintendo Wii® system (Nintendo of America, Redmond, Washington) uses unique motion sensing technology to determine the location of handheld controllers, called the Wii remote® and Wii nunchuk, and lower body movement is sensed from the Wii Balance Board® which is placed on the floor. The ability for game designers to demand movements for game play success has allowed for exercise themed games to be created.

One such exercise themed game “Nintendo Wii Fit®” is a game that includes over 40 exercises in four different components of fitness [23]. The four components of fitness training include strength, yoga, aerobics and balance (See Table 1 for a full list of exercises).

Strength and yoga exercises are accomplished by following an on screen trainer who demonstrates proper technique; endurance and balance games incorporate on screen mini games such as snowboarding or boxing to complete these exercises [23]. The Wii Fit exercise game offers varying difficulty levels for each fitness component, ranging from easy to moderate to hard. Wii Fit uses the Wii remote, Wii nunchuk, and Wii Balance Board for the completion of Wii Fit activities so that both upper and lower extremity movement is required during game play.

Table 1. Nintendo Wii Fit® Exercises by category

Category	Strength	Endurance	Yoga	Balance
Exercises	• Single leg extension • Sideways Leg Lift • Arm and Leg Lift • Single-Arm stand • Torso Twists • Rowing Squat • Single Leg Twist • Lunge • Push-up and Side plank • Jackknife • Plank • Tricep Extension	• Hula-hoop • Basic Step • Basic Run • Super Hula Hoop • Advanced Step • 2-person Run • Rhythm boxing • Free Step • Free Run	• Deep breathing • Half-moon • Dance • Cobra • Bridge • Spinal Twist • Shoulder Stand • Warrior • Tree • Sun salutation • Standing knee • Palm tree • Chair • Triangle • Downward Facing Dog	• Soccer heading • Ski slalom • Ski Jump • Table tilt • Tightrope walk • Balance Bubble • Penguin Slide • Snowboard Slalom • Lotus Focus
Challenges	• Push-up • Plank • Jackknife			

The use of the Nintendo Wii® to promote physical activity seems promising. The popularity of the Wii implies greater access to exercise themed games, which allows for interventions to be developed that could reach larger population. Initial studies that have examined energy expenditure of active gaming indicate that energy expended while playing the Nintendo Wii® is greater than traditional game play and resting energy expenditure [21, 24, 25]. Knowing the energy expenditure of an activity is important because it allows for caloric expenditure to be determined and is also used in the calculation of an activity's intensity level.

Exercise activity intensity level is very important for use in the prescription of exercise to the public. Research has shown that physical activity training adaptations occur due to a combination of three factors: frequency, intensity, and duration of exercise. Current guidelines state that the frequency and duration of physical activity recommendations change based on an exercise's intensity level [3]. Intensity level is typically defined by metabolic equivalents which indicate the number of times above resting energy expenditure that an activity requires. One MET is equal to the amount of energy that the body expends at rest [1]. ACSM and the CDC use metabolic equivalents to quantify intensity level of an activity and state that moderate activities require 3.0 to 5.9 METs, and vigorous intensity activities are defined as 6.0 METs and above[3]. The activity recommendations suggest that individuals participate in at least 150 minutes of moderate intensity or 75 minutes of high-intensity aerobic activity each week[3]. Compendia of physical activity intensities have been previously developed to help differentiate the intensity level between everyday activities; the Nintendo Wii® is not currently one of the included activities [26, 27]. The intensity levels of Wii exercise themed games are unknown, and whether or not these games should be recommended in interventions as moderate intensity physical activities is not clear. To prescribe appropriate activity to an individual and accurately estimate energy expenditure while playing Wii exercise games, the intensity levels of these games must be known.

Therefore it is important to know the intensity of the Nintendo Wii Fit® exercise game prior to prescribing that activity in an intervention.

Purpose of the Study

Given the potential for the Nintendo Wii® to become a valuable physical activity intervention tool, a need for research to understand the effects of active gaming has arisen. Therefore, the purpose of this study was to determine intensity levels of playing several selected Nintendo Wii® fitness games using indirect calorimetry. From the measured energy expenditure, the intensity levels of the Nintendo Wii Fit® activities were determined. Using the intensity information, it was determined if playing Wii Fit (an exercise themed game) on the Nintendo Wii® video game console met the ACSM moderate physical activity guideline threshold. A controlled experimental design was employed to determine the physical activity intensity and energy expenditure of playing Wii Fit.

Research Hypotheses

The Nintendo Wii® system increases total body movement when compared to traditional video games [20, 25]. It was hypothesized that:

a) The Nintendo Wii system would generate more energy expenditure than resting energy expenditure levels.
b) Playing the selected Nintendo Wii Fit® exercise themed games would not meet the ACSM guidelines for moderate intensity exercise.
c) Intensity level calculated from indirect calorimetry would be greater for the moderate difficulty level Wii exercises when compared to the easy difficulty level exercises.

Operational Definitions

Physical Activity

Physical activity is any bodily movement that is a result of a skeletal muscle contraction that requires energy to be expended. Physical activity progressively increases health benefits based on increases to any one of the components for physical activity [1].

Intensity

Intensity is defined as how hard a person is working during physical activity. Intensity level in resistance training is determined by the amount of weight lifted; in aerobic exercise, speed and grade affect intensity.

Duration

Duration is the length of time that a physical activity bout lasts.

Frequency

Frequency is defined as the number of physical activity sessions per week.

Energy Expenditure

Energy expenditure will be defined as the amount of energy consumed to complete a certain task and will be expressed as a MET.

Resting Metabolic Rate

The amount of energy used by the body to maintain the vital processes during rest.

Measured Resting Metabolic Rate

A measured resting metabolic rate measured through indirect calorimetry.

Standardized Resting Metabolic Rate

A standardized resting metabolic rate of 3.5 mL/kg/min developed for all individuals.

Metabolic Equivalent (MET)

One MET represents the amount of energy that is being expended at rest, expressed in mL/kg/min^{-1}. To calculate the MET intensity of a given exercise, exercise energy expenditure will be divided by the resting metabolic rate.

Measured MET

The MET value calculated from measured energy expenditure and a measured resting metabolic rate.

Calculated MET

The MET value calculated from measured energy expenditure and the standardized resting metabolic rate of 3.5 mL/kg/min.

Active video game

For the purpose of this study, an active video game is any video game that requires additional movement beyond just pressing buttons with the thumbs or trigger fingers.

Significance of the Study

Physical activity is a very important aspect of living a healthy life [1, 3]. Since physical activity levels are decreasing throughout all age ranges, the development of physical activity interventions that utilize popular technologies is essential for reversing the current trend of decreased physical activity participation. The health costs of an increasingly inactive U.S. population are starting to take a toll on the health care system and depleting health care resources [9, 28-30]. Physical activity benefits on health and well being have been well documented over the years, yet many people are unaware of the physical activity recommendations developed by ACSM [3, 6] and are still living sedentary or less active lifestyles. Video game popularity on the other hand seems to be increasing every year and technology has advanced enough to allow for exercise themed home video games to be developed [31]. Therefore, it is essential to determine the intensity level of these exercise themed games so that the amount of energy that is expended in these new activities can be quantified. This will allow experts to determine if these exercise themed games meet the minimum recommendations of moderate physical activity levels.

Study Limitations

The time commitment of the participants is not extremely high, but participants will be asked to attend four sessions to complete the data collection. Due to the availability of only one Wii system, only one participant can complete the exercise protocol at a time. Therefore, scheduling 25 participants for four sessions could eliminate some potential participants due inflexible schedules.

The Nintendo Cooperation of America has set forth guidelines, for the Nintendo Wii® and the Wii Balance board. The most important of these guidelines was that player weights not exceed 135.87 kilograms. This limitation on the study population limits the ability to see how the Nintendo Wii® could handle more massive populations potentially including extremely obese individuals.

Study Delimitations

This study will be limited in scope to primarily college aged adults. This could negatively impact recruitment of subjects because the study population is so specific. Since most college age students fall within a certain age range, it is likely the sample will have a similar narrow age range. Due to these facts, the ability to generalize the data to the children and older adult populations will be difficult because all ages will not be represented.

Due to the unique features of the Nintendo Wii®, familiarity with the system could play a role in the results. To help eliminate variability in Wii system, participants will be limited in prior Wii Fit experience.

CHAPTER 2

LITERATURE REVIEW

Introduction

The purpose of this literature review is to provide more in depth information on: the relationship between physical activity and health, physical activity guidelines, energy expenditure, energy expenditure measures, active video game energy expenditure research, and physical activity changes due to culture. The first section of the literature review will explore the relationship between physical activity and health, provide the physical activity guidelines, and explain energy expenditure. The second section of the literature review will analyze criterion and field based energy expenditure measures, to better understand the choice of methodology in this study and past studies. The third section will examine previous active video game research, and come to a consensus about most often used methodologies and main results of these studies. The last section of the literature review will examine physical activity and culture. The purpose of this section is to examine how the adaptation of culture plays a role in the physical activity participation and physical activity type preference.

Physical Activity and Culture

Physical activity is an important component to a healthy lifestyle. The unpredictability of culture and its environment has changed the physical activity landscape through technological developments and changes in cultural trends. Many studies have found that current physical activity trends are showing significant decreases in physical activity level during aging [8]. This trend towards more sedentary behavior has the potential to lead to weight gain and decreased physical fitness levels across all age groups [5]. Sedentary behavior leads to decreased energy expenditure, which when combined with increased energy intake will lead to weight gain. Technology has been a large reason for the decrease in physical activity, although it is not entirely to blame. Increased demand on individuals to perform well in school or at work has led to more time being spent on sedentary activities. For example the core curricula outlined in the No Child Left Behind act is academically oriented which could lead to increased computer use, and sedentary study behavior in childhood age groups. Entertainment options for individuals have shown similar trends of moving towards more sedentary activities including watching television, video games, computers and cell phones [5]. These changes in technology are an example of how the environment in which individuals are living has promoted sedentary behavior. The culture has changed as well. Many studies have examined the relationship between work hours, socioeconomic status, race and age related to health or physical activity. These studies have found that work hours have an effect on physical health, while physical activity participation is affected by socioeconomic status and work hours [15, 32]. The decreasing activity levels seen in these studies could mean that current interventions and exercise modalities are not sufficient or are not successful at promoting and maintaining physical activity.

Intervention studies have examined technology as a possible solution rather than as the problem. These studies have attempted to show that the use of technology can be a valid intervention tool that helps maintain program adherence. The primary intervention method of these studies was to use video games as the tool to promote physical activity [33,

[34]. The use of technology in physical activity interventions shows promise, since all ages are spending more time using technology in everyday life [31, 35]. Studies have compared exercise adherence in traditional exercise training programs to exercise programs that use video games and found that adherence rates were higher in adolescents when using video games as part of the protocol [34]. The use of technology in exercise interventions could possibly be an important part of reversing current physical inactivity trends.

To further understand the need to incorporate physical activity into video game play, an understanding of video gamer profiles is need. A recent study by Williams et al. has done ground breaking work examining the characteristics of gamer preferences on and off game consoles. This study found that 40% of adults and 83% of teenagers play video games, that the average age of players has recently risen to 33 years old and that the average amount of time spent playing video games was 25 hours per week or above in all age ranges after 22 years of age [31]. Interestingly the average number of hours played each week increased progressively with age [31]. Comparing these data with longitudinal studies examining physical activity indicate that as physical activity decreases with age, game playing increases. If an active video game was developed that was well liked by gamers, utilization of this game even for a fraction of the total playing time would help to increase physical activity and possibly meet ACSM physical activity guidelines. Unfortunately, very little research has been done to determine if these physical activity games would be intense enough to substitute for traditional exercise.

<u>Physical Activity and Health</u>

There are many factors that play a role in health, one of which is the amount of physical activity in which individuals engage. The positive contributions of physical activity toward improved health have been vetted through extensive research [1, 3, 4, 36, 37]. Researchers have shown that the health benefits from physical activity occur at any activity level, although this research has also found a direct relationship between activity intensity and health benefits [1, 3, 36, 37]. Specifically, the higher the intensity level of activity, the greater the overall health benefits [1, 3, 36]. A cut off point for significant health benefits is at or above moderate physical activity intensity (≥3METS) [1, 3, 4, 36, 37].

Strong evidence suggests that increasing physical activity will decrease the risk of many hypokinetic health conditions. Chronic physical activity participation will decrease the risk of an early death by improving overall health and decreasing chronic disease rates [1, 3]. Physical activity participation elicits increased energy expenditure, blood flow, heart rate, blood pressure, muscle contraction and respiratory rate, which encourage physiological adaptations that benefit health.

Physical activity helps to prevent weight gain by acutely increasing energy expenditure during and immediately after exercise [1, 3, 4, 37]. Chronically, the prevention of adipose tissue gain occurs through an increase in lean body mass and regulation of diet. Physical activity adaptation to the lean tissues includes an increase in size (muscles, organs), which increases lean body mass [1]. The resting metabolic rate of an individual could be directly related to lean body mass; theoretically by increasing lean tissue, more energy would than need to be consumed by the body at rest, which helps to maintain total body weight. The combination of physical activity with restricted caloric intake will result in weight loss [3]. This happens due to the body's increase in daily energy expenditure while decreasing its energy intake, resulting in the breakdown of stored energy in the body (fat).

Physical activity also helps to improve cardiorespiratory and muscular fitness [3]. The training adaptation to muscles and the cardiovascular system from chronic physical activity are a common goal of many training protocols. Muscles adapt to activity by increasing in size (hypertrophy), strength, and stamina (muscular endurance). Hypertrophy and strength adaptations occur from loading muscles with resistance which helps to improve neurological control of muscles and increase muscle fiber size [1, 38]. Cardiorespiratory fitness adaptations occur by placing stress on the system through higher intensity activities. The heart is a muscle and will adapt similarly to training like skeletal muscle does by becoming larger (hypertrophy) and more efficient [1, 38]. Overall, the body becomes more efficient at transporting oxygen to various systems and removing waste such as carbon dioxide [1, 38].

Physical activity also helps with the improvement of many other health factors. Activity levels decrease depression levels by causing the release of hormones in the body that are associated with happiness [1, 3]. Improvements and adaptations to the skeletal system also occur as a result of physical activity participation [3]. During activity, the bones of the body are loaded with the forces of the activity which cause the bones to reform and adapt to the external forces, this remodeling theory is known as Wolfe's Law [1, 3]. In older adults, physical activity helps to improve cognitive function, functional health, reduce the risk of bone fracture, and prevent falls [1, 3, 36]. Lastly, physical activity also helps to reduce the risk of many cancers such as lung and endometrial cancers [3]. Clearly, physical activity participation is crucial to health, as evidenced by all of the health benefits stated above. To help encourage people to obtain these health benefits, guidelines for physical activity intensity, frequency and duration were developed, so that people could refer to the guidelines and understand the activity requirements to improve their health.

Guidelines for Physical Activity

The American College of Sports Medicine (ACSM), and the U.S. Department of Health and Human Services: Centers for Disease Control and Prevention (CDC) have developed recommendations for the minimal level of physical activity required to augment health. ACSM and CDC have determined that frequency, intensity and length of exercise all play a significant role in training and health adaptations [4, 7]. *Duration* is simply the amount of time that is spent performing a physical activity at a given time. *Frequency* is the number of physical activity sessions that occur during a given time period such as a week (how many exercise sessions a week). Lastly, *intensity* level of the exercise is the amount of work that is being performed during the activity. There are two methods for defining intensity: in absolute and relative terms.

There are two ways to provide data: absolutely or relatively. Absolute data is the raw score of a test, while relative data is the raw score divided by some other measured criteria. The primary reason for calculating relative data is that it allows for a better comparison between participants. For example if there were two people that performed a max bench press test, one lifts 100 kilograms while the other only lifts 50 kilograms. From these absolute scores the individual that lifts 100 kilograms would be considered stronger. To get a relative score for each participant the max bench press weight would be divided by body mass for example; which would allow for a better comparison to be made between subjects. If both individuals had a mass of 50 kilograms, and strength was calculated relative to body mass the second subject would be stronger per pound of body weight. This would allow the researcher to examine these absolute conditions by standardizing them to some measured criteria of the population. According to the CDC and ACSM, absolute intensities are given in the form of metabolic equivalents, which are discussed later under energy expenditure. Absolute intensities are divided into three broad categories. Light-intensity activities require between 1.1 and 2.9 METs, moderate activities require 3.0 to 5.9 METs, and vigorous intensity activities are defined as 6.0 METs and above [3]. Relative intensity is given as a percentage of a physiological parameter such as heart rate, heart rate reserve or aerobic capacity [3]. For the purpose of this study, absolute intensity will be used to define intensity level for a given workload. Absolute intensities will be the most "user friendly" and translatable to the lay person.

ACSM and CDC developed general guidelines for physical activity that recommend a frequency of 3-5 days a week, a duration of 20-60 minutes and an intensity of 55-90% of max heart rate (MHR) [4, 7]. CDC has developed age specific recommendations for adults which recommend at least 150 minutes of moderate intensity or 75 minutes of high-intensity aerobic activity a week to have extensive health benefits [3, 4]. Furthermore, activity should be done in bouts that last a minimum of 10 minutes and activity should be spread throughout the week [3, 4]. Strength training is another important component of physical activity for adults and should be of a moderate to high intensity at least 2 days a week [3, 4]. Additional health benefits will occur with additional exercise above these recommended minimum levels and by no means indicate individuals should only be this active.

The guidelines for physical activity developed by ACSM, and CDC, do not directly state specific intensities, frequencies and durations guidelines for weight loss.

Any activity resulting in energy expenditure above resting levels has the potential to help in weight management. The ACSM, and CDC all state that diet and exercise need to be modified together to result in healthy weight loss [3, 4]. If an individual is expending more energy than is being ingested, weight loss will be the result. Furthermore, physical activity levels required to maintain weight or result in weight loss can vary between individuals. Higher intensity exercise results in more energy expended compared to a lower intensity exercise for the same time period, which indicates the increased value of higher intensity exercise as a weight management tool.

The development of physical activity guidelines for the minimum level of activity required to maintain good health has helped individuals to plan and execute activity training programs. These guidelines can be used for the assessment of physical activity and the prescription of exercise. Exercise frequency, duration and intensity are all used to determine if these minimum standards have been met.

Energy Expenditure

For physical activity guidelines to be developed, researchers needed to understand energy expenditure and its relationship to exercise intensity. The body needs energy to maintain basic life functions and to perform everyday tasks. Energy expenditure is expressed in kilocalories (kcal) per unit of time. A kilocalorie is the amount of energy it takes to raise one kilogram of water one degree Celsius [1]. Energy expenditure is a method for determining the intensity of an activity, but it needs to be measured first.

There are many ways to measure energy expenditure. The criterion measure (the measurement everything is compared to) for energy expenditure is calorimetry; there are two forms of calorimetry: indirect and direct. Direct calorimetry measures actual changes in temperature, which can then converted to energy expenditure [39]. Unfortunately, it is very difficult to quantify the amount of heat that is being produced by the body in free living conditions. Indirect calorimetry measures changes in oxygen uptake and carbon dioxide production which are then used for energy expenditure prediction [40-42]. The amount of oxygen that is consumed by the body per minute is known is oxygen consumption $\dot{V}O_2$.

Many field measures have been developed to allow for the estimation of energy expenditure without the use of a laboratory. The use of heart rate monitoring to estimate energy expenditure is valid because of its linear relationship to oxygen consumption ($\dot{V}O_2$) at submaximal workloads [43, 44]. Accelerometers measure movement to estimate the amount of energy that is being expended [45, 46]. Work and power output devices have recently been developed to measure change in position, time, elevation; which allows for a better estimation of exercise intensity and energy expenditure estimation [47, 48]. Various combinations of these devices have been used to increase the validity of energy expenditure estimation [49-52]. The main difference between field and criterion measures is that field measures are estimating energy expenditure and are validated against the indirect criterion measures of calorimetry.

Energy expenditure in kilocalories can be calculated using metabolic equivalents (MET), which quantify energy expended by the amount of oxygen that is consumed per kilogram of body weight per minute. In an attempt to make $\dot{V}O_2$ measurements from calorimetry or predictions from field tests more comparable, oxygen consumption scores are converted to MET values [26, 27]. One MET is the equivalent to the amount of oxygen in milliliters consumed per kilogram of body mass per minute, when the body is at rest (the standard used if RMR cannot be measured is 3.5mL O_2 /kg/min) [1]. Subjective data can also be used to estimate MET values through the use of physical activity questionnaires and subjective self reported activity intensity. Converting energy expenditure into METs allows for measures other than changes in heat to be used in the quantification of energy expenditure.

Quantifying Physical Activity Intensity

Physical activity is defined as bodily movement that causes energy expenditure above the basal metabolic rate [1]. To allow researchers to develop physical activity recommendation intensities based on the relationship between exercise $\dot{V}O_2$ and resting metabolic rate, the measurement of $\dot{V}O_2$ is required. Oxygen consumption is measured or predicted through a variety of tools that vary in validity, reliability, cost, and overall functionality. As previously stated, exercise intensity is often expressed as metabolic equivalents or METs [26, 27]. The relationship between exercise intensity and $\dot{V}O_2$ shows that $\dot{V}O_2$ increases linearly as intensity increases, which allows for METs to be used as a definition of intensity. The ability for researchers to estimate or measure $\dot{V}O_2$ is important because $\dot{V}O_2$ varies based on activity type and intensity.

The need to determine $\dot{V}O_2$ and related intensity level of active video games is essential to further the development of these technology driven activity interventions. Researchers have many tools and devices to quantify $\dot{V}O_2$ through measurable variables that can then be converted into $\dot{V}O_2$ units if it is not directly measured. All of these measures have been developed using adult subjects, which works for the purpose and population of the current study [53]. A review of literature was conducted to determine the most valid and reliable $\dot{V}O_2$ measure for use in adults while participating in activity.

Many of the current exercise protocols base $\dot{V}O_2$ estimations off of maximal exercise testing. A maximal level of exercise in adults has been reached when of the following three criteria for maximal exercise testing criteria are met. The three criteria for a maximal exercise test are: reaching within 10 beats per minute of the age predicted max heart rate, having a respiratory exchange ratio above 1.1 (the ratio between CO_2 production and $\dot{V}O_2$) and a plateau in $\dot{V}O_2$ [1]. If two of these criteria are met the test is considered a $\dot{V}O_2$peak, if all three criteria are met the test is considered a $\dot{V}O_2$max. In children, all testing is considered a $\dot{V}O_2$peak even if all three criteria are met because a child may not fully understand the need to go to an all out effort. These max tests are used to find the relationship between field and criterion measures, allowing for the conversion of field results into $\dot{V}O_2$ estimations. The relationship calculated between a field and criterion devices must use the same activity type and be the same in both field and laboratory settings.

Indirect calorimetry is the criterion measure for $\dot{V}O_2$. Often new protocols and measures are validated against the measurement of calorimetry since it is shown to be the most reliable and accurate measure. Direct calorimetry is not used in oxygen consumption measurement because it is the direct measure of changes in bodily heat, which is not beneficial for use in free living conditions such as during physical activity. Indirect calorimetry directly measures oxygen consumed and carbon dioxide produced [41, 54].

There are two primary methods used in indirect calorimetry: doubly labeled water and direct gas analysis. The doubly labeled water (DLW) method utilizes unique isotopes of oxygen and hydrogen, which are ingested into the body through specially formulated water. Changes in concentration of these isotopes, when measured after a period of time, allows for $\dot{V}O_2$ to be calculated [40, 42, 55]. This method is also expensive and requires highly trained lab technicians familiar with isotope concentration calculation. The DLW method is similar to direct calorimetry in that it measures total body $\dot{V}O_2$ and is not a valid or reliable measure of instantaneous $\dot{V}O_2$ [54]. The other form of indirect calorimetry direct gas analysis is better suited to deal with the instantaneous requirements of exercise $\dot{V}O_2$ measurement.

Gas exchange systems measure the amount $\dot{V}O_2$ and the amount of carbon dioxide produced ($\dot{V}CO_2$). There are two types of gas exchange systems: closed circuit systems and open circuit systems. Both system designs have strengths and weaknesses. Closed circuit systems are isolated systems that prevent external air from entering the circuit. These measurements can only be used for short durations due to the decrease in oxygen available and the amount of carbon dioxide produced from respiration [41]. The inability of these systems to last longer than a short duration severely limits these systems in measuring most physical activities. The duration of measurement depends on the amount of air in the system; a larger volume will allow for a longer amount of time, typically these systems can handle measurements up to a minute or two.

Open circuited systems, on the other hand, can be utilized for instantaneous measurements of oxygen consumption over longer durations. These systems are open to external air sources through the use of a one-way valve so the test can last as long as needed and expired air is collected and analyzed [41]. Open circuit systems use gas analyzers to measure $\dot{V}CO_2$ and $\dot{V}O_2$, which is used to calculate activity intensity. Original systems required manual air collection into Douglas bags. Once collected the air is fed into the automated gas analyzers to determine $\dot{V}CO_2$ and $\dot{V}O_2$ [56]. Current systems have eliminated the need for Douglas bags, and have allowed for the instantaneous and continuous collection of data. These systems are expensive, and until recently, have been limited to use in a laboratory.

Portable gas exchange systems have been developed to increase the functionality of gas exchange systems. These systems run off of batteries and allow for $\dot{V}CO_2$ and $\dot{V}O_2$ to be measured directly in the field with near instantaneous results [41, 56]. Developers continue to enhance these systems in an effort to improve the validity and reliability of the gas analysis measurement. The primary issue with these systems is the comfort factor of the participant being measured. Generally these portable systems are strapped to the chest or hip and have a tube running from the analyzer to a mouth piece. Even though these portable systems have been designed from the fixed systems, there is still a need to validate them [56]. The design and placement of these systems make them fragile and expensive, which makes it difficult to justify use in some sport specific activities. Many other devices have been developed and validated against calorimetry; these devices are called field measures. These devices are often less expensive and easier to use, but do so at the expense of validity and reliability. Accelerometers, heart rate monitors, work output devices and combinations of multiple field measures are often used in place of calorimetry.

Accelerometers are portable, small devices that allow the investigator to place it and essentially forget about it. Accelerometers fit into two different categories: uni-axial or multi-axial devices [57]. These devices record the number and intensity of movements that are occurring within each axis. Uni-axial accelerometers measure force generation in one direction or axis. Generally this is oriented to measure changes in hip location in the vertical axis. Tri-axial accelerometers are used to measure forces in three orthogonal axes (x, y, and z). Accelerometry is an evolving field, and devices are constantly being upgraded. Many studies have been done validating various accelerometry devices [45, 58, 59]. A key issue with accelerometers is that no standards have been accepted as to what constitutes a movement; the movement counts collected are then used to predict activity intensity [60, 61]. Due to this and the large number of different equations used, there is a large amount of variability in estimated $\dot{V}O_2$ and calculated MET values from accelerometers. The ease of use of these devices make them simple to use in large population studies where errors will be diluted due to the large number of subjects as seen in many of the aforementioned studies.

Heart rate has long been the physiological measure of choice in exercise. It has been used in the development of exercise guidelines and is even included internally on many pieces of exercise equipment. Heart rate is an effective way to estimate exercise intensity, but only above a threshold of 120 beats per minute. Prior to reaching 120 bpm, heart rate is affected by both the sympathetic and parasympathetic nervous systems, reducing the reliability of intensity estimations below the rate of 120 bpm [44, 53, 62]. If the exercise that is being measured is a very low intensity sub-max exercise, then heart rate might not be the best measure because that activity will likely not cause a heart rate above 120 bpm increasing the error of energy expenditure calculation. To develop an individual equation for $\dot{V}O_2$ estimation, heart rate needs to be calibrated to indirect calorimetry.

The calibration of heart rate to indirect calorimetry occurs by simultaneously recording both heart rate and $\dot{V}O_2$ during physical activity. Heart rate monitors can then be worn in the field during the activity, and an estimation of energy expenditure can then be made [51, 62, 63]. A significant caveat for the reliability of this method is that it is only valid for a similar activity, i.e. if an individual wishes to estimate energy expenditure of running, then the $\dot{V}O_2$/heart rate calibration test should be from a running test [64]. Heart rate can be a valid way to estimate $\dot{V}O_2$ on a population basis when pre-test calibration is completed with calorimetry. Heart rate monitors are relatively inexpensive and a non-invasive device that does not inhibit comfort or movement. These devices are often used simultaneously with other field measures, such as accelerometers, to increase the reliability of other field measures.

Combining other field measures with heart rate is a relatively recent method for estimating $\dot{V}O_2$ and exercise intensity. Combined devices that record movement and heart rate are in development; until these new devices become more readily available; many studies use the individual devices at the same time [49-51, 63, 65]. These combination devices have lowered the $\dot{V}O_2$ prediction error in laboratory settings compared to a single field device $\dot{V}O_2$ predition[49, 63, 66]. To further decrease the error in field based measures, branched equation modeling is then used to estimate $\dot{V}O_2$ using the output from these devices, taking into account activity type [63]. The continued research and development of these devices might lead to a change in $\dot{V}O_2$ prediction devices, but at the current time these combination devices have not been extensively validated [51].

Work output devices have very recently been developed from traditional uses such as location triangulation to estimate physical activity intensity and $\dot{V}O_2$. These devices have been developed from global positioning system devices (GPS) that record environmental characteristics, velocity, acceleration, elevation change and exercise duration [47, 48, 67, 68]. These devices alone are not enough to estimate $\dot{V}O_2$, and are often used with an additional physiological measure such as heart rate [67, 69]. Power and work can be calculated with the data collected from the GPS devices which when combined with physiological parameters such as heart rate allow for predictions of exercise intensity. Currently, work output meters have not been used solely to estimate $\dot{V}O_2$; however, use with other devices (HR monitors or accelerometers) has shown promise [67, 69]. GPS devices are getting smaller, more accurate and less expensive, but at the current time, they should not be used in studies until further validation has been done.

Video Game Energy Expenditure Research

Current research in energy expenditure has begun to examine the amount of energy expended while using an active video game system. These studies have primarily examined active arcade video games such as "Dance Dance Revolution" [19, 20, 70, 71]. Many studies have also examined active video game play in home based video game consoles, but fail to examine exercise based games [21, 24, 25, 33]. Research studies that have examined home based video game systems primarily used traditional popular games that demanded lower intensity activity while playing, such as Wii sports [21, 24, 72]. Some of the aforementioned studies also compared active video game consoles to the energy expended while playing traditional sedentary video game consoles.

The purpose of the aforementioned studies was to determine the energy expenditure, intensity level and motivation to play active video games. By determining energy expenditure and intensity level of these active video games recommendations, can be made on the use of these games as physical activity tools. Energy expenditure research of dance simulation games such as Dance Dance Revolution has been found to meet ACSM guidelines of minimum intensity exercise [20, 70]. The positive results of these studies show that active arcade video games do increase energy expenditure, which increases the need for future research in this area. Research on home active video game consoles has found increases in energy expenditure when compared to traditional video game consoles [24, 25]. Another study examining active video game consoles found that energy expenditure was higher when game play promoted bilateral movements [21]. These studies show promise for active fitness video games to demand at least light intensity level of exercise while playing.

According to ACSM and CDC, light intensity exercise should not be the primary form of exercise since moderate and vigorous activity are recommended, but completely inactive individuals or those suffering from disease may not be able to achieve higher levels of activity intensity [3, 30]. Theoretically the results of these active video game console studies should be expected, energy expenditure should increase in these situations due to the total body movement that is required compared to the unilateral movements and the sedentary nature of traditional consoles. Maddison et al. [13] examined energy expenditure of the Playstation 2 (Sony's version of the active console) active games and found that the intensity of the game equated to light to moderate physical activities [13, 72]. This is a promising result, albeit from one study, that indicates energy expenditure of active exercise games could be higher than light intensity. As exercise video games continue to be developed, research needs to be conducted to determine the intensity level of the various games and validate these games as legitimate physical activities.

All of the previous energy expenditure research on video games has helped to develop the best methodology for quantifying energy expenditure during these activities. Many different field and criterion measures have been used throughout these studies. Indirect calorimetry was used in many of the studies either as a direct measure or a way of validating a field measure [20, 21, 25, 34, 70, 72]. Accelerometers have been used in many studies as a field measures if indirect calorimetry was too difficult to use [13, 24]; other studies have used accelerometers in sync with indirect calorimetry [21, 72]. Accelerometers can be an excellent field measure for estimating energy expenditure in adults, as discussed previously.

Heart rate is the other field measure that is used to estimate energy expenditure, although heart rate was never used as the sole measure [20, 21, 25, 34, 70]. These studies used heart rate in conjunction with another measure such as indirect calorimetry. All of the aforementioned studies had the participants play the video game for a minimum of five minutes or longer. The reason for this is that after three to five minutes at a constant workload, the body reaches a steady state of energy expenditure for that workload. Reaching steady state gives the researcher the most accurate measure of energy expenditure during active video game play.

Summary

Research in physical activity is essential to develop a further understanding of the factors that influence energy expenditure. ACSM and CDC have found that physical activity no matter what duration, intensity, and frequency will elicit positive adaptation; a need for minimum guidelines for activity intensity were developed because at the recommended levels more significant health benefits occur. To better understand and prescribe new physical activities the intensity level and energy expenditure of that activity need to be known to determine if the activity meets the minimum guidelines for exercise intensity.

Determining which energy expenditure measure to use is a difficult process. The type of activity, the data to be collected, the availability of equipment, and the cost and validity of these measures all need to be considered when choosing the appropriate device. Criterion measures should be used when available and appropriate since these measures are the most accurate on an individual basis. Direct calorimetry is an excellent measure of resting energy expenditure over long periods, but lacks the ability to perform well measuring instantaneous changes in energy expenditure during exercise. Indirect calorimetry is an excellent lab based measure for energy expenditure because of its ability to instantaneously and accurately measure energy expenditure and has been used in previous active video games studies. In certain situations the laboratory based measurements of energy expenditure are not great choices due to availability, cost or the type of exercise or movement.

Field based measures provide scientists the ability to still collect energy expenditure data without the need for lab access. Accelerometers are relatively cheap and can record data for extended periods of time, yet studies have shown that energy expenditure estimation from accelerometry alone has error. Heart rate monitors are cheaper than accelerometers and also have the ability to store large amounts of data; unfortunately differences in participant fitness level and other factors affect heart rate and can alter energy expenditure estimation. Combining field measures for estimating energy expenditure offer a more accurate method than HR or accelerometry alone. The combination of work output devices, accelerometers, and/or heart rate monitoring has been shown to be more accurate in the few studies completed to date and may indicate a future for this method. Heart rate monitors when calibrated against indirect calorimetry have shown to be an accurate predictor of population energy expenditure.

Many studies examining trends of physical activity have came to some frightening conclusions regarding the activity levels of individuals at all ages. These studies show trends that activity is declining due to changes in culture, specifically due to the education system and the further reliance on technology. Research using technology as a physical activity intervention has found that active video games have a relative intensity level of low to moderate. These findings will help game developers to enhance active video games to increase energy expenditure and the intensity level of the games. The lack of studies examining the Nintendo Wii® fitness video games indicates a need for scientific research in this area. Past research is beneficial to the present study because methodologies have been developed and enhanced to provide the best estimation of energy expenditure in video game research.

CHAPTER 3

METHOD

Participants

A set of exclusion and inclusion criteria were used to select appropriate participants for this study. Prior to starting any form of the study, participants were asked to sign an informed consent form (approved by the Boise State Institutional Review Board [IRB].) Participants then completed a variety of questionnaires to help determine if the participant met all of the inclusion criteria for the study. A Physical Activity Readiness Questionnaire (PAR-Q), the International Physical Activity Questionnaire (IPA-Q), and a medical history questionnaire were completed to determine health status and physical activity level. This information was reviewed and it was then determined if the participant was eligible for the study.

The primary purpose of the study was to determine the physical activity intensity of selected Nintendo Wii Fit® exercise games through the measurement of energy expenditure by indirect calorimetry. Individuals who were taking any metabolic medications such as beta blockers or diet pills, which would affect metabolic rate, were not recruited to participate in the study. Metabolic medications affect energy expenditure by increasing resting metabolic rate or decreasing resting metabolic rate, these changes affect the calculated intensity level, which would have led to inaccurate study results.

Pre-exercise health risk determined from pre-study surveys was considered. High risk individuals were excluded from the study to prevent further injury from occurring.

The Nintendo Wii® utilizes activity from all four limbs to satisfactorily complete Wii Fit exercises; therefore individuals with previous self-reported injuries that currently limit mobility in any of the four limbs were not recruited since it affected that individual's ability to complete the selected activities. Video game play has been associated in the past with seizures and manufacturers warnings are presented on each system, therefore individuals with previous seizure episodes or epilepsy diagnosis were not recruited for participation [23, 73]. To adhere and comply with the manufacturer guidelines for the Wii Balance board state (i.e., participant weight should not exceed 135.87 kg), a participant was excluded from the study if his/her body weight exceeds 135.87kg.

An age range of 18-29 years was employed in the study because of the measurement of RMR. During the aging process, decreases in lean body mass generally occur which has a direct effect on RMR [74]. To determine individual exercise intensities for the Nintendo Wii, RMR was measured for each participant. RMR is a process that is affected significantly by age, as an individual ages RMR will decrease. Therefore, age was controlled within the study to eliminate the effect of age on RMR.

Studies have shown that individuals with higher physical activity levels are able to complete an activity more efficiently and thus require less energy expenditure. The participants self-reported physical activity levels and an IPAQ score was collected for each individual so the amount of physical activity participation for each participant was controlled in data analysis to eliminate the potential influence of physical activity levels on physical activity intensity. The IPAQ score was a total summed score from the participants IPAQ questionnaire, in total MET/min per week. Self reported data was also be used to determine an individual's Wii experience. New motor tasks are shown to have a learning effect following multiple bouts or attempts at a similar task. To eliminate variability in learning effect, individual Wii usage was less than 10 previous bouts.

The unique design and features of the current study made it difficult to find a suitable study to conduct a power analysis. A power analysis was conducted based on the most similar study conducted by Sell et al. [19] to determine an estimate for the sample size required for this study. An a priori analysis indicated that a sample size of 29 will be needed to have adequate power ($p>.80$). To ensure that the sample size of the current study was close to meeting the power analysis results a sample size of at least 80% of 29 was required. A bonferoni correction was applied so the alpha level was set at $\alpha= (.05)/6= .01$ because six different activity comparisons were being conducted. Therefore 35 college aged male and female participants, were recruited for this study to allow for a 10-15% dropout rate. Participants were then randomly assigned to an exercise testing order using the table below. Admitted participants, rolled a dice and to determine the starting point for the exercise sessions.

Each of the six exercises was assigned a number so that each participants roll of the dice had an equal chance of selecting one of the six exercises. The first exercise visit started with the exercise determined from the dice roll; the second and third exercises were the next two sequentially numbered exercises. The second exercise visit testing order continued with the next sequentially numbered exercise followed in order by the final two exercises(e.g., if a 3 was rolled then the first exercise of the fourth visit would be exercise #6, followed by #1 and #2).

Table 2. Randomly assigned activity protocol

	Strength Exercises	Endurance Exercises	Yoga Exercise
Difficulty: Low	Lunges (1)	Basic Run (2)	Warrior (3)
Difficulty: Moderate	Single Leg Extensions (4)	Basic Run (5)	Chair (6)

Participants were recruited from the Boise State University campus through the use of e-mails, posted announcements, and word of mouth. Participants were asked to make four visits into the Human Performance Lab in the Kinesiology Building at Boise State University. As a way to increase participation, subjects were offered a free hydrostatic body composition test.

Measures

Anthropometrics and general health

Standard demographic information (age, gender, weight, height, and Wii usage) were collected and general overall health was measured using a general survey developed for use in this study. Height was measured by having the participant stand against a wall with a 200 cm tape measure. A ruler was then placed perpendicular to the wall atop the participants head and then the participant stepped away from the wall. Height measurements were rounded to the nearest half centimeter.

In addition, body mass of each participant was measured by a BWB-800S Digital Scale (Tanita Corporation of America, Arlington Heights, IL, United States). To ensure proper calibration of this device, a calibrated mass was placed on the scale prior to weighing each subject. If the scale did not accurately read the correct calibration weight, the scale was adjusted accordingly. The participant stood still on the scale until the scale was no longer fluctuating.

Resting heart rates were measured by palpation on each participant prior to the collection of RMR data. Heart rates were determined over a 1 minute count to ensure the most valid measure of resting heart rate. The resting heart rate data was then used in the determination of the rest duration between each activity. The participant was required to rest between activities until the measured heart rate had dropped below 120% of the RHR. This was done to ensure that the previous activity had no carryover effects on the determined intensity level of the next exercise.

Physical Activity Level

The Physical Activity Readiness Questionnaire (PAR-Q), and the International Physical Activity Questionnaire (IPA-Q), were completed by each participant to assess potential health risk. A revised version of the Physical Activity Readiness Questionnaire (PAR-Q) (Canadian Society for Exercise Physiology, Ottowa, Ontario) was used to determine if a doctor needed to be consulted prior to physical activity. The PAR-Q has been validated for use with 15-69 year old individuals [75, 76].

The International Physical Activity Questionnaire (IPA-Q) (Karolinska Institute, Sweden) was used to determine self-reported physical activity level. The IPA-Q determined the amount of time spent in physical activity and has been validated for use in 15-69 year olds [77, 78]. Category 1 individuals were considered inactive and were indicated by a raw IPAQ score of less than 600 MET-min/weeks. Category 2 individuals self reported moderate activity levels and were indicated by a raw IPAQ score of between 600 MET-min/weeks and 3000 MET-min/week. Category 3 individuals were considered highly active and were indicated by a total MET-min/week score of 3000 or greater.

Body Composition

Body composition was measured to allow for relative intensity levels (to lean body mass) to be calculated for each individual. Relative intensity values were calculated by taking the MET value and dividing it by lean body mass calculated from skin fold (see equations below) or hydrostatic measurement. All participants were given the opportunity to do a hydrostatic test as an incentive to participate in the experiment. A select number of those individuals that do a hydrostatic weighing had skinfolds taken to ensure tester reliability with skinfold measurement. All other participants had a skinfold analysis done.

The sites vary based on the sex of the participant: the chest, abdomen and thigh were used for males, and the triceps, anterior suprailliac and thigh were used for females. These skinfold measurements allow for body density to be calculated which was then used in the calculation of body fat % using the three site prediction equation developed by Siri [79- 82]. The validated Jackson- Pollock body density equation and the Siri three site prediction equations were used to calculate body fat % [79-82]. A Harpenden skin caliper (Baty International, Sussex, England) was used to measure the skinfold thickness, in millimeters, with scores rounded to the nearest tenth of a millimeter. A minimum of two measurements was taken at each site; and an average of the two scores was used in the body density prediction equations. If the two measurements from one site were not within 3 mm of the previous reading additional readings were taken. After body density was calculated, another prediction equation, developed by Heyward et al [83] was used to calculate the predicted body fat percentage [83]. The following prediction equations were used to calculate body density and fat percentage, respectively [80, 81]:

Figure 1. Body Composition Equations

$$\text{Male Body Density} = 1.10938 - 0.0008267(\text{sum of three site avereages in mm}) + 0.0000016(\text{sum of three site averages in mm})^2 - 0.0002574\,(\text{age})$$

$$\text{Female Body Density} = 1.099421 - 0.0009929(\text{sum of three site avereages in mm}) + 0.0000023(\text{sum of three site averages in mm})^2 - 0.0001392\,(\text{age})$$

$$\text{Male Body Fat Percentage} = \left(\frac{495}{\text{BodyDensity}}\right) - 450$$

$$\text{Female Body Fat Percentage} = \left(\frac{501}{\text{BodyDensity}}\right) - 457$$

$$\text{Lean Body Mass} = \text{Total Body Mass} \times (100 - \text{Body Fat \%})$$

To ensure safety and privacy, trained female graduate students helped with the data collection on female participants and males collected data on males. Female graduate assistants collected skinfolds, assisted the female participants with proper heart rate monitor placement, and assisted the principle investigator during metabolic data collection. The same female and male investigator completed all data collection sessions to control the variability between testers. All data collectors were taught and tested on proper skinfold measurement technique. Furthermore, each research assistant passed a skinfold technique test by comparing measurements on a participant that had completed a hydrostatic densitometry underwater weighing.

Activity Intensity

Polar Heart Rate Monitors

Polar heart rate monitors (Polar Electro, Tampere, Finland) were used to monitor heart rate during video game play. To ensure that one of the assumptions of measuring $\dot{V}O_2$ with a metabolic cart was met, it was important to measure heart rate along with oxygen consumption to ensure that a steady state was reached. A steady state was important to the determination of each activities intensity level because it ensures that the measured intensity of that activity was consistent when the measurement occurred. The linear relationship between heart rate and $\dot{V}O_2$ at sub maximal workloads between 100 bpm and 90% of max heart rate allows heart rate to be the determining factor of steady state exercise. Heart rates in two consecutive minutes must have a difference $\leq$ 5 beats per minute to be considered steady state exercise. The use of Polar heart rate monitors to measure heart rate change during physical activity has been validated to accurately measure heart rates during different activities [84]. Heart rates were recorded during the last ten seconds of each minute of exercise and compared to other minutes. The heart rate data was used solely for the determination of steady state exercise and played no role statistical role in the analysis of the activities intensities.

TrueMax 2400 Metabolic Cart

A TrueMax 2400 Metabolic Cart (ParvoMedics, Salt. Lake City, Utah, USA) was used to assess $\dot{V}O_2$ and $\dot{V}CO_2$ during Wii game play and was found to be a valid device for measuring gas consumption and production during exercise and at rest [85-87]. Participants completed a ten minute resting metabolic rate prior to the exercise protocol visits to determine a measured resting metabolic rate [88, 89]. During game play, the TrueMax software automatically recorded gas consumption/production on a breath to breath rate throughout the exercise duration and averaged all data into 30 second intervals. Oxygen uptake was converted into METs, which allowed for metabolic comparisons to the physical activity intensity norms (Figure 2). Oxygen consumption data was recorded in milliliters per kilogram per minute, liters per minute and milliliters per kilogram of lean body mass (LBM) per minute. MET intensities were calculated by dividing oxygen consumption (mL/kg/min, L/min, mL/kg LBM/min) by the resting metabolic rate collected for each subject (mL/kg/min, L/min, mL/kg LBM/min) [1]. Metabolic Equivalents (MET) are used in the ACSM Physical Activity Guidelines to provide intensities for different levels of activity, and thresholds for various health benefits.

Procedure

This study consisted of 3 to 4 visits and took approximately 3-4 hours for each participant to complete. Due to the sub-maximal nature of the exercise the participants were allowed to schedule visits on consecutive days.

Visit 1: Orientation/Informed Consent/ Questionnaires/Wii familiarity meeting (approximately 1.5 hours)

The initial visit was held in the Human Performance Laboratory at the Boise State University Kinesiology building. A presentation was given to inform potential participants about the purpose/goals of the study, the protocols and instrumentation that was used to measure $\dot{V}O_2$ and to introduce the Nintendo Wii® system. The attendees were given the opportunity to ask questions that were answered by the principal investigator.

After completion of the introductory presentation, participants were given an informed consent form to read and sign that was approved by the Boise State University Institutional Review Board. Following the agreement to participate, participants were asked to complete questionnaires to determine activity level and health risk using (PAR-Q, IPA-Q, and general health questionnaire) three questionnaires. The questionnaires were reviewed and participants that passed the screening for study enrollment based on the aforementioned exclusion/inclusion criteria were scheduled for the second visit. Participants were instructed to dress for activity, fast for 12 hours, and refrain from vigorous physical activity six hours prior to arrival at visit two.

Visit 2: Body Composition/Resting Metabolic Rate (approximately .5 hr)

Prior to the arrival of each participant, the metabolic cart was calibrated using the protocol provided with the TrueMax software (Appendix B). The calibration of the metabolic cart was conducted by the principle investigator for each visit to ensure calibration validity. Each participant's height and weight was measured and recorded for input into the metabolic computer. The data collector took skinfold measurements of the participant and calculated estimated percent body fat.

The participant was then asked to sit down and relax for 20 minutes prior to the RMR measurement. The TrueMax 2400 metabolic cart (ParvoMedics, Salt. Lake City, Utah, USA) was then connected to the participant to begin the RMR measurement. The RMR measurement lasted for 10 minutes, while the participant maintained a comfortable position. A resting heart rate for the participant was recorded prior to the start of RMR measurement, for use in 120% RHR calculation. The participants that were recruited for the study were then given at least 30 minutes to play and become more familiar with the Wii system. Upon completion of the visit participants scheduled the third appointment and were given the opportunity to ask any additional questions. Participants were reminded to refrain from high intensity physical activity for 24 hours prior to visit 3.

Visit 3: Wii Fit Exercise Session 1 (approximately 1 hr)

Prior to the arrival of each participant, the metabolic cart was calibrated using the protocol provided with the TrueMax software (Appendix B). Polar heart rate monitors (Polar Electro, Tampere, Finland) were then fitted to the participants; participants then completed a five minute warm up by walking at a self selected ungraded speed on a treadmill. The participant was then connected to the TrueMax 2400 metabolic cart (ParvoMedics, Salt. Lake City, Utah, USA).

The participant then completed the exercise protocol; the randomly assigned exercise order from visit one was used to determine the exercise difficulty and order. Prior to the start of each exercise a Nintendo Wii® demonstration of that exercise was shown to each participant. Additional technique and form instructions were given to the participant to ensure the proper completion of each activity. Exercise difficulties on the Nintendo Wii Fit® included low, moderate, and hard and exercise types included strength, endurance, balance and yoga. For the simplicity of this study only low and moderate difficulty exercise types were used in strength, endurance, and yoga Wii Fit activities.

Refer to table 2 for a full layout of the selected activities. Strength exercises were completed as 3 sets of the selected strength exercise. Single leg extensions (moderate difficulty) and lunges low difficulty were the strength exercises completed. Endurance exercised consisted of a running-type exercise and was the Basic Run Short and the Basic Run Long on the game. Yoga exercises were not varied based on an explicit difficulty level and consisted of one exercise repeated throughout the yoga set. The yoga exercises included the Warrior Pose and the Chair Pose. Endurance and yoga exercises continued for a minimum of three minutes until a steady state was reached. Steady state was determined by measured heart rates in consecutive minutes with less than five beats per minute variability.

Participants were given a rest period in between exercise sets, to ensure no effect from the previous exercise. The rest period duration was relative to each participants resting heart rate and rest occurred until the participants heart rate had dropped below 120% of resting heart rate. Heart rates were recorded every 30 seconds and input into the metabolic cart computer, gas analysis averages were automatically computed by the metabolic cart ever 30 seconds.

Upon completion of the exercise protocol participants cooled down walking on a treadmill until the recovery heart rate had fallen within 30 beats of resting heart rate to ensure a proper cool down. Participants then scheduled the fourth appointment and were given the opportunity to ask any additional questions. Participants were reminded to refrain from high intensity physical activity for 24 hours prior to visit 4.

Visit 4: Wii Fit Exercise Session 2 (approximately 1 hr)

Visit four followed the same protocol as visit three. Participants completed the second randomly assigned exercise protocol as determined from the dice roll.

Data Analysis

SPSS 18.0 (Chicago, IL, USA) was used for all statistical analyses. Descriptive statistics were calculated for age, gender, height, weight, body mass index, skinfold calipers body composition, Wii familiarity and IPAQ average. Mean statistics were calculated for the resting physiological parameters of resting heart rate, 120% resting heart rate, and resting metabolic rate. Mean statistics were calculated for each exercise type including oxygen consumption and MET intensity. A paired sample t-test was run to determine if there was a statistical difference between the measured resting metabolic rate and the predicted resting metabolic rate of 3.5 mL/kg/min. A full copy of all statistical results can be made available upon request.

Gas analysis data from the final two minutes of each steady state exercise were used to calculate $\dot{V}O_2$ in endurance and yoga type exercises. In strength exercises, gas analysis data was averaged across the three sets to calculate total average energy expenditure. Oxygen consumption was then converted into METs intensity levels for each activity using the measured resting metabolic rate and the calculated resting metabolic rate (Figure 2). Relative intensities for all MET scores were determined by dividing $\dot{V}O_2$ by lean body mass and body mass.

Figure 2: Metabolic Equivalent Equations used to calculate exercise intensity

$$\text{Met Intensity} = \frac{\text{Exercise } \dot{V}O_2}{\text{Resting } \dot{V}O_2\,(\text{RMR})}$$

$$\text{Met Intensity with Predicted RMR} = \frac{\text{Exercise } \dot{V}O_2}{\frac{3.5\text{mL}}{\text{kg}}/\text{min}}$$

Absolute intensities were determined by dividing the absolute oxygen consumption in L/min by the absolute RMR in L/min. To get a relative intensity the exercise oxygen consumption and RMR were converted into mL/kg/min and mL/kg of lean body mass/min.

To test the first hypothesis, a set of one sample t-test with an adjusted alpha level of .05/6 = .008 was used to determine if exercise $\dot{V}O_2$ were significantly higher than resting levels by comparing the calculated and measured mean MET values of each exercise with 1 MET (resting $\dot{V}O_2$).

To test the second hypothesis, a set of one-tail one sample t-test with an adjusted alpha level of .05/6 = .008 was used to determine if playing the Nintendo Wii Fit® games meets or exceeds the moderate intensity level (>= 3 METs) of physical activity recommended by ACSM.

To test the third hypothesis, a set of paired sample t-test with an adjusted alpha level of .05/6 = .008 was used to determine if the higher difficulty level exercises caused significantly higher intensities when compared to the easy difficult level exercise activities.

To ensure that self reported physical activity score had no effect on the intensity level of the exercises, a correlation was run on all calculated and measured MET values for each exercise. The correlation was done on absolute MET values, relative to body mass MET, and relative to lean body mass MET values.

Finally, a paired sample t-test was done to see if there was a significant difference in MET values for each activity between measured MET values and calculated MET values. Calculated MET values came from the standardized RMR for all individuals and the measured MET values were calculated from the measured RMR.

CHAPTER 4

RESULTS

The primary purpose of this study was to determine the intensity levels of several selected Nintendo Wii Fit® fitness games using indirect calorimetry. Exercise $\dot{V}O_2$ were measured for each activity type and converted into MET values by dividing the activity $\dot{V}O_2$ by the measured and standardized resting metabolic rates. The measured exercise $\dot{V}O_2$, measured resting metabolic rate and standardized resting metabolic rate were compared in absolute values (L/min), and relative to body mass (mL/kg/min) and lean body mass (mL/kg of lean body mass/min), respectively. The MET intensities of each activity were compared to the ACSM Guidelines for physical activity to determine if the Wii Fit® game meets the moderate intensity thresholds.

Characteristics of Participants

Twenty-five participants volunteered for the study: twenty females and five males. Table 3 shows the descriptive data of participants overall and separated by gender. The mean age of the female participants was 22.35 years ± 1.98 (mean ± SD), and was 21.80 years ± 2.86 for the males. The mean height for the females was 166.66cm ± 5.84, and was 176.53cm ± 7.128 for the males. The average mass of the females was 62.55kg ± 7.41, and 82.34kg ± 10.69 for the males. The female participants had a mean body fat percentage of 18.75% ± 6.40, and a Body Mass Index of 22.54 ± 2.65. The male participants had a mean body fat percentage of 14.57% ± 4.48, and a Body Mass Index of

26.3927 ± 2.53. All twenty- five participants had played the Nintendo Wii Fit® game fewer than ten times. The raw IPAQ scores reported in MET minutes per week appeared to differ between genders, with males having higher scores than females. There was no statistically determined significant difference between genders, t (23) = 1.801, p= 0.085.

Table 3. Descriptive Statistics of Participants by Gender

	Women Mean ± SD (n=20)	Men Mean ± SD (n=5)	Total Mean ± SD (n=25)
Age (Years)	22± 2	22 ± 3	22 ± 2
Height (cm)	166.66 ± 5.84	176.53 ± 7.128	168.63 ± 7.19
Mass (kg)	62.55 ± 7.41	82.34 ± 10.69	66.50 ± 11.30
IPAQ Score (MET-min/week)	3997± 2882	6427 ± 1567	4483 ± 2823
Body Mass Index (kg/m^2)	22.6 ± 2.65	26.4 ± 2.53	23.4 ± 3.014
Body Fat %	18.8 ± 6.40	14.6 ± 4.48	18.0 ± 6.22
Lean Body Mass (kg)	50.5 ± 5.49	70.1 ± 8.18	54.4 ± 9.97

Descriptive Results of Resting Physiological Data

An overview of the resting physiological data is provided in Table 4. Resting heart rates were taken to determine the rest threshold duration. The resting heart rate values were higher in women (64.15bpm ± 8.69) compared to men (62.2bpm ± 5.67). Standardized and measured resting metabolic rates were determined in an absolute $\dot{V}O_2$ (L/min), relative $\dot{V}O_2$ to body mass (mL/kg/min) and relative $\dot{V}O_2$ to lean body mass (mL/kg LBM/min). The measured resting metabolic rates were significantly higher than the standardized resting metabolic rates in absolute RMR t (24) = 2.7, p < 0.05, relative to body weight RMR t (24) = 2.6, p< 0.05 and relative to lean body mass RMR t (24) =

2.6, $p < 0.05$ measures. The absolute RMR values in both the measured and standardized values were significantly higher in men when compared to women, the t statistics ranged from 1.8 to 3.9, when the degrees of freedom was 23, which resulted in a $p < .05$.

Table 4. Resting physiological data by gender

	Females Mean ± SD (n=25)	Males Mean ± SD (n=25)	Total Mean ± SD (n=25)
Resting Heart Rate (bpm)	65 ± 9	63 ± 6	64 ± 8
Measured RMR (L/min)	0.234 ± .033[a]	0.308 ± .052[a]	0.249 ± .0473[b]
Measured RMR (mL/Kg/min)	3.76 ± 0.48	3.71 ± 0.44	3.75 ± 0.46[b]
Measured RMR (mL/kg of Lean Body Mass/min)	4.66 ± 0.63	4.39 ± 0.61	4.61 ± 0.62[b]
Standardized RMR (L/min)	0.219 ± .026[a]	0.288 ± 0.037[a]	0.233 ± .0396[b]
Standardized RMR (mL/Kg/min)	3.5	3.5	3.5[b]
Standardized RMR (mL/kg of Lean Body Mass/min)	4.35 ± 0.35	4.11 ± 0.22	4.30 ± 0.34[b]

Note: Standardized RMR was the general resting oxygen consumption of 3.5 mL/kg/min for all individuals. Measured RMR was the individually measured metabolic rate. Statistical Results: a= significantly different RMR compared between genders. b= significantly different RMR compared between measured and standardized RMR values for each unit type (L/min, mL/kg/min, mL/kg LBM/min).

Descriptive Results of Wii Activities

A mean $\dot{V}O_2$ and MET intensity level was found for each activity. Refer to Figures 3, 4 and 5 for a graphical representation of mean $\dot{V}O_2$ and MET intensity level by activity. The mean absolute $\dot{V}O_2$ for the selected activities ranged from 0.57 for the yoga warrior activity to 1.40 L/min for the medium aerobics basic run. The relative $\dot{V}O_2$ data ranged from 8.53 mL/kg/min to 20.98 mL/kg/min in the same respective exercises. The aerobics themed activities had the largest mean $\dot{V}O_2$ and MET values. Second in intensity level were the strength activities, followed by the two yoga poses.

Medium Difficulty Level Activities

Yoga Chair.

The synopsis of the yoga chair activity data is provided in Table 5 and 6. The exercise duration was three minutes for most participants, while a few participants went longer in duration. To calculate the $\dot{V}O_2$ of the yoga chair activity the last two minutes of each participant's exercise duration was used. There was no statistical difference between the heart rates of males and females during the yoga chair activity. The t values ranged from -.5 to -2.0 with degrees of freedom = 23, the p ranged from 0.061 to .672. The minute that all females had the lowest heart rate was the first minute with a heart rate of 109.6 bpm ± 15.60, and females peaked during minute two at 111.4 bpm ± 13.26. The men peaked during the second minute of exercise at 98.2 bpm ± 13.92 and were lowest during the third minute at 97.4 bpm ± 13.39. Females consumed slightly less oxygen, and had an intensity level that was a little lower than males' intensity and $\dot{V}O_2$. Overall, the average intensity level for the Yoga Chair exercise was 2.51 ± 0.36 for the measured MET and 2.68 ± 0.47for the calculated MET, respectively as shown in Figure 3. The mean average $\dot{V}O_2$ was 9.36 (mL/kg/min) ± 1.67 as shown in Figures 4 and 5.

Strength Single Leg Extension.

The synopsis of the Strength Single Leg Extension activity data is provided in Table 5 and 6. The exercise duration was typically three minutes, while a few participants went longer in duration. Average $\dot{V}O_2$ was calculated from the metabolic cart data throughout the duration of each participants' exercise time. There was no statistical difference between the heart rates of males and females during the strength single leg extension activity. The t values ranged from -0.6 to -2.0 with degrees of freedom = 23, the p ranged from 0.053 to .573. The minute that all women had the lowest heart rate was the first minute with a heart rate of 116 bpm ± 13, and the women peaked during minute three at 119 bpm± 15. The men peaked during the second minute of exercise at 109 bpm ± 14 and were lowest during the third minute at 104 bpm ± 14. Women consumed slightly less oxygen, and had an intensity level that was a little lower than men intensity and $\dot{V}O_2$. Overall, the average intensity level for the Strength Single Leg Extension activity was 3.3 ± 0.71 for the measured MET and 3.48 ± 0.59 for the calculated MET as shown in Figure 3. The mean average $\dot{V}O_2$ was 12.13 (ml/kg/min) ± 2.02 as shown in Figures 4 and 5.

Aerobics Basic Run Long.

The synopsis of the Aerobics Basic Run Medium exercise data is provided in Table 5 and 6. The exercise duration was four minutes long for each woman and three minutes for men, while a few participants went longer in duration. The last two minutes of the aerobics basic run long, metabolic cart data were used for each participant. There was no statistical difference between the heart rates of males and females during the aerobics basic run long activity, except during minute two when females had a significantly higher heart rate, t (23) = -2.5, $p<.025$. The t values ranged from -1.6 to -2.4 with degrees of freedom = 23, the p ranged from 0.03 to .12. The minute that all women had the lowest heart rate was the first minute with a heart rate of 126 bpm ± 16, and the women peaked during minute four at 137 bpm ± 18. The men peaked during the third minute of exercise at 122 bpm ± 16 and were lowest during the first minute at 110 bpm ±

20. Women consumed slightly less oxygen, and had an intensity level that was a little lower than men intensity and $\dot{V}O_2$. Overall, the average intensity level for the Aerobics Basic Run Medium exercise was 5.73 ± 1.36 for the measured MET and 6.04 ± 1.09 for the calculated MET as shown in Figure 3. The mean average $\dot{V}O_2$ was 20.98 (mL/kg/min) ± 3.65 as shown in Figures 4 and 5.

Table 5. Wii Activity Intensity Levels (METs) at Medium Difficulty Level

	Yoga Chair Mean ± SD (n=25)		Aerobics Basic Run Medium Mean ± SD (n=25)		Strength Single Leg Ex. Mean ± SD (n=25)	
	Measured MET	Calculated MET	Measured MET	Calculated MET	Measured MET	Calculated MET
Absolute Data (MET)	2.51 ± 0.36[abc]	2.68 ± 0.47[abc]	5.73 ± 1.36[abc]	6.04 ± 1.09[abc]	3.30 ± 0.71[a]	3.48 ± 0.59[ab]
Relative to body mass (MET)	2.5 ± 0.37[abc]	2.67 ± 0.48[abc]	5.69 ± 1.34[abc]	6.0 ± 1.05[abc]	3.28 ± 0.71[a]	3.47 ± 0.58[ab]
Relative to lean body mass (MET)	2.5 ± 0.37[abc]	2.67 ± 0.48[abc]	5.69 ± 1.34[abc]	5.99 ± 1.04[abc]	3.28 ± 0.71[a]	3.47 ± 0.58[ab]

Note: Measured MET was determined using the measured RMR. Calculated MET was determined with the standardized RMR. Significant Statistical Results: a= different MET value when compared to 1 MET (resting). b= different MET compared to 3 MET (moderate intensity). c= different MET value when compared between active type (strength, yoga, aerobics) and difficulty level (easy, medium).

Table 6. Wii Activity $\dot{V}O_2$ at Medium Difficult Level

	Yoga Chair Mean ± SD (n=25)	Aerobics Basic Run Medium Mean ± SD (n=25)	Strength Single Leg Ex. Mean ± SD (n=25)
Absolute $\dot{V}O_2$ (L/min)	0.62 ± 0.019	1.40 ± 0.041	0.81 ± 0.134
$\dot{V}O_2$ Relative to Body Mass (mL/kg/min)	9.36 ± 1.67	20.98 ± 3.65	12.13 ± 2.02
$\dot{V}O_2$ Relative to Lean Body Mass (mL/kg/min)	11.11 ± 1.17	25.43 ± 4.30	15.27 ± 1.62

Easy Difficulty Level Activities

Yoga Warrior.

The synopsis of the Yoga Warrior exercise data is provided in Table 7 and 8. The exercise duration was four minutes long for each participant, while a few participants went longer in duration. Average $\dot{V}O_2$ was calculated for each participant using the last two minutes of the metabolic cart data. There was no statistical difference between the heart rates of males and females during the yoga warrior activity. The t ranged from 0.116 to -1.810 with degrees of freedom = 23, the p ranged from .083 to .912. The lowest level heart rate for a time interval that included all females was 105 ± 16 and peaked at 110 ± 16 during the fourth minute. The time interval that all men had the lowest heart rate was during the first minute at 92 ± 9 and peaked at 97 ± 10 during the fourth minute. Women consumed slightly more oxygen, and had an intensity level that was a little higher than men intensity and $\dot{V}O_2$. Overall, the average intensity level for the Yoga warrior exercise was 2.30 ± 0.42 for the measured MET and 2.44 ± 0.38 for the calculated MET as shown in Figure 3. The mean average $\dot{V}O_2$ was 8.53 (mL/kg/min) ± 1.33 as shown in Figures 4 and 5.

Strength Lunge.

The synopsis of the Strength Lunge exercise data is provided in Table 7 and 8. The exercise duration was four minutes long for each women and five minutes for men, while a few participants went longer in duration. Oxygen consumption for the strength lunge exercise was calculated by taking an average across the entire exercise duration. There was no statistical difference between the heart rates of males and females during the strength lunge activity. The t ranged from 0.175 to -1.902 with degrees of freedom = 23, the p ranged from 0.869 to 0.07. The minute that all women had the lowest heart rate was the first minute with a heart rate of 115 bpm ± 13, the women peaked during minute four at 119 bpm± 17. The men peaked during the fifth minute of exercise at 104 bpm ± 9 and were lowest during the first minute at 109 bpm ± 9. Women consumed slightly less oxygen, and had an intensity level that was a little lower than men intensity and $\dot{V}O_2$. Overall, the average intensity level for the Strength Lunge exercise was 3.18 ± 0.62 for the measured MET and 3.38 ± 0.57 for the calculated MET as shown in Figure 3. The mean average $\dot{V}O_2$ was 12.01 (mL/kg/min) ± 2.10 as shown in Figures 4 and 5.

Aerobics Basic Run Short.

The synopsis of the Aerobics Basic Run Easy exercise data is provided in Table 7 and 8. The exercise duration was three minutes long for each participant, while a few participants went longer in duration. The measured $\dot{V}O_2$ from the last two minutes of each participant's exercise time was used to calculate the aerobics basic run short average MET. There was no statistical difference between the heart rates of males and females during the aerobics basic run long activity. The t ranged from 0.813 to -1.026 with degrees of freedom = 23, the p ranged from 0.316 to 0.573. The minute that all women had the lowest heart rate was the first minute with a heart rate of 120 bpm ± 12, the women peaked during minute three at 128 bpm ± 13. The men peaked during the third minute at 123 bpm ± 25 and were lowest during the first minute at 113 bpm ± 18. Women consumed slightly less oxygen, and had an intensity level that was a little lower than men intensity and $\dot{V}O_2$. Overall, the average intensity level for the Aerobics Basic Run Easy exercise was 4.98 ± 1.22for the measured MET and 5.26 ± 1.00 for the calculated MET as shown in Figure 3. The mean average $\dot{V}O_2$ was 18.34 (mL/kg/min) ± 3.52 as shown in Figures 4 and 5.

Table 7. Wii Activity Intensity Levels (METs) at Easy Difficulty Level

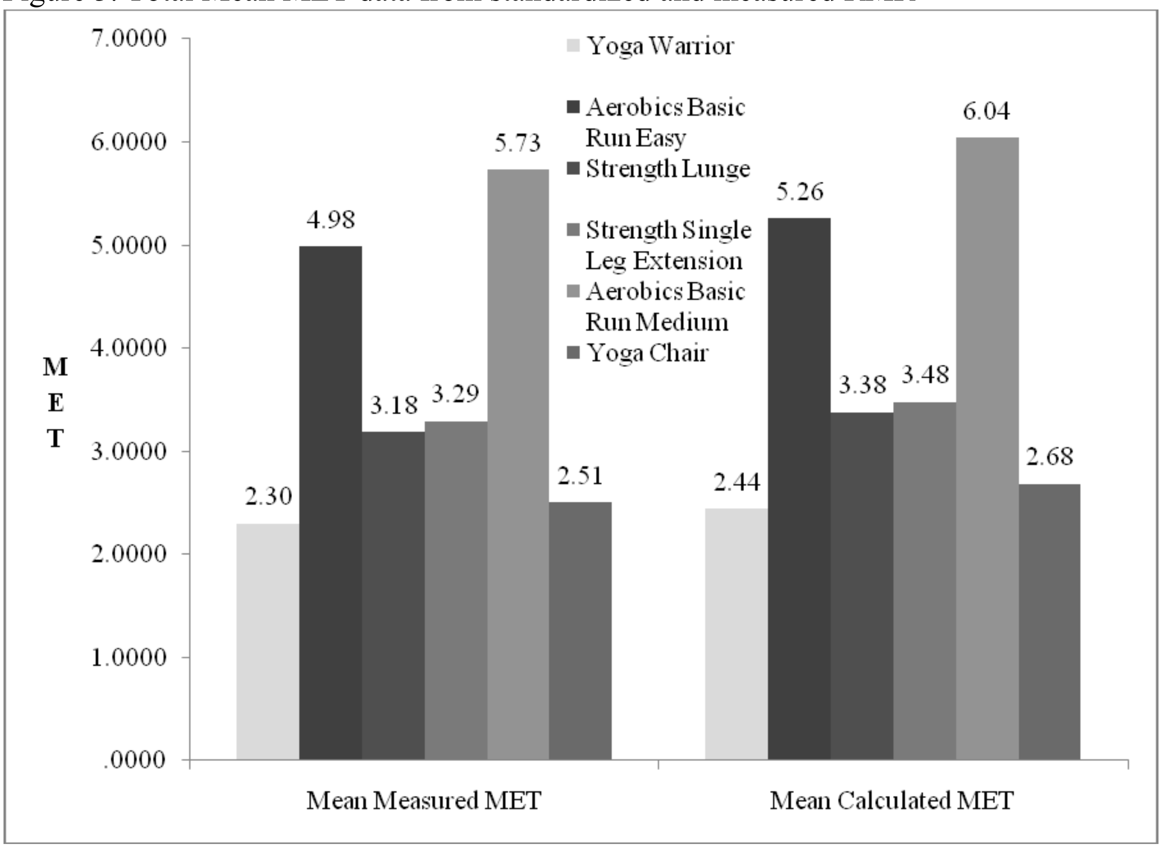
	Yoga Warrior Mean ± SD (n=25)		Aerobics Basic Run Easy Mean ± SD (n=25)		Strength Lunges Mean ± SD (n=25)	
	Measured MET	Calculated MET	Measured MET	Calculated MET	Measured MET	Calculated MET
Absolute Data (MET)	2.30 ± 0.42[abc]	2.44 ± 0.38[abc]	4.98 ± 1.22[abc]	5.26 ± 1.00[abc]	3.18 ± 0.62[a]	3.38 ± 0.57[ab]
Relative to body mass (MET)	2.30 ± 0.42[abc]	2.44 ± 0.38[abc]	4.97 ± 1.23[abc]	5.24 ± 1.00[abc]	3.23 ± 0.60[a]	3.43 ± 0.60[ab]
Relative to lean body mass (MET)	2.30 ± 0.42[abc]	2.44 ± 0.38[abc]	4.97 ± 1.23[abc]	5.24 ± 1.00[abc]	3.23 ± 0.60[a]	3.43 ± 0.60[ab]

Note: Measured MET was determined using the measured RMR. Calculated MET was determined with the standardized RMR. Significant Statistical Results: a= different MET value when compared to 1 MET (resting). b= different MET compared to 3 MET (moderate intensity). c= different MET value when compared between active type (strength, yoga, aerobics) and difficulty level (easy, medium).

Table 8. Wii Activity $\dot{V}O_2$ at Easy Difficult Level

	Yoga Warrior Mean ± SD (n=25)	Aerobics Basic Run Easy Mean ± SD (n=25)	Strength Lunges Mean ± SD (n=25)
Absolute $\dot{V}O_2$ (L/min)	0.57 ± 0.015	1.22 ± 0.040	0.80 ± 0.024
$\dot{V}O_2$ Relative to Body Mass (mL/kg/min)	8.53 ± 1.33	18.34 ± 3.52	12.01 ± 2.10
$\dot{V}O_2$ Relative to Lean Body Mass (mL/kg/min)	10.48 ± 1.8	22.58 ± 4.69	14.74 ± 2.77

Figure 3. Total Mean MET data from standardized and measured RMR



Note: Measured MET was determined using the measured RMR. Calculated MET was determined with the standardized RMR. Standardized RMR refers to 3.5mL/kg/min of oxygen consumption. Measured RMR refers to a directly measured RMR via indirect calorimetry.

Figure 4. Mean Absolute Oxygen Consumption (L/min) by Exercise Type

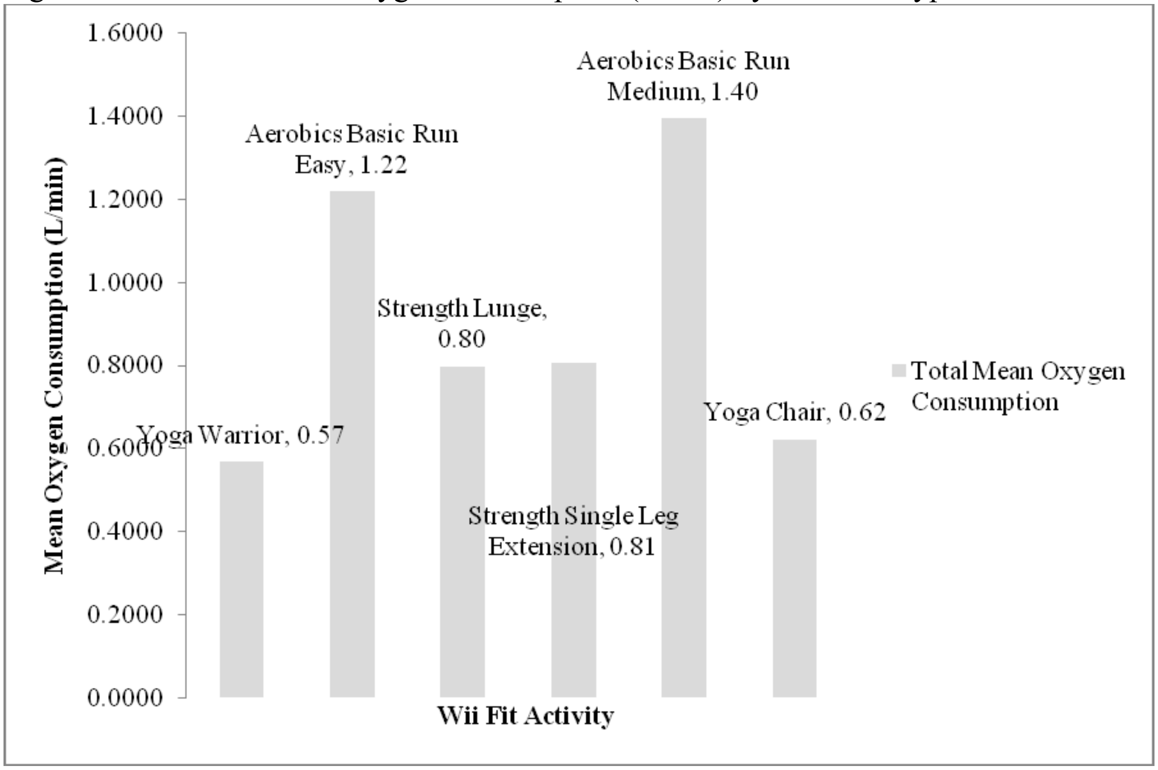
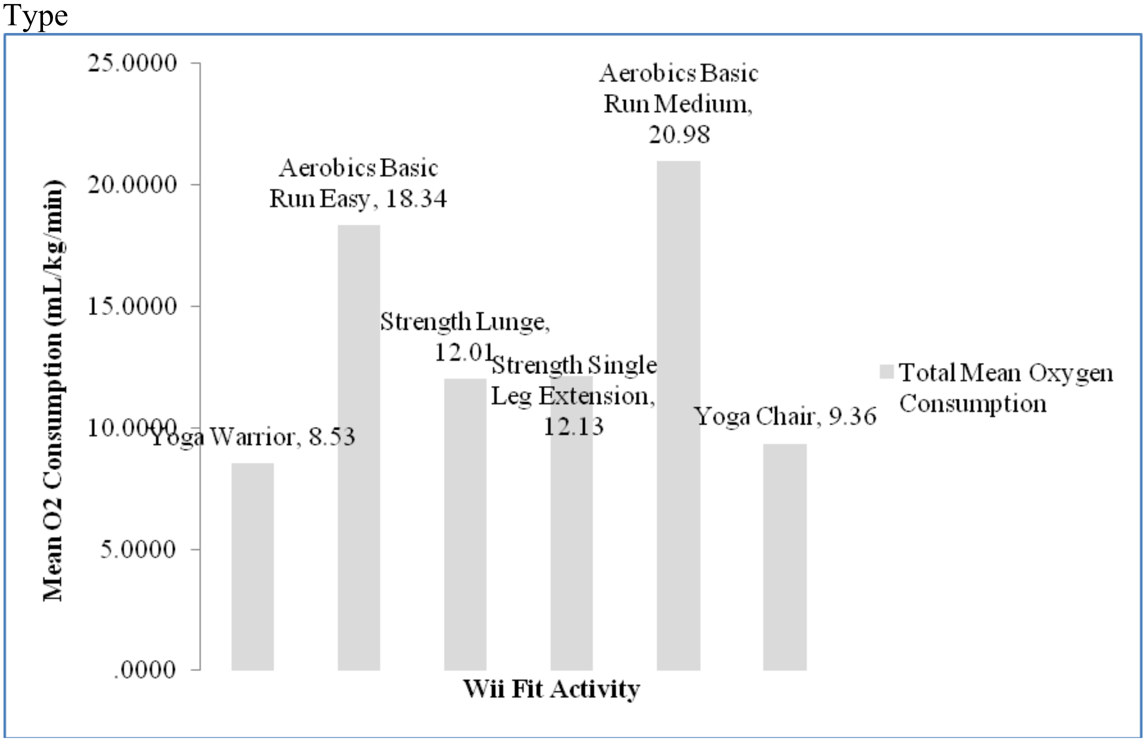


Figure 5. Mean Relative Oxygen Consumption (mL/kg of body mass/min) by Exercise Type



Statistical Inference Results for Selected Wii Fit Activities

Hypothesis 1

A set of one sample t-tests was conducted to examine if the selected Wii Fit activities had significantly higher $\dot{V}O_2$ compared to resting $\dot{V}O_2$ levels. Refer to Tables 5-8 for a synopsis of the activities MET scores and $\dot{V}O_2$. The comparison was done for each exercise using the absolute, relative to body mass, and relative to lean body mass measured $\dot{V}O_2$ with both standardized and measured resting metabolic rate with significant level being adjusted using bonferroni correction. The lowest oxygen demanding exercise activity was the Yoga Warrior exercise. The mean measured MET score for the Yoga Warrior was 2.30 ± 0.42 for the measured MET and had a t (24) = 15.5, p-value < 0.01. The mean calculated MET score for the Yoga Warrior was 2.44 ± 0.32 and had a t (24) = 19.1, p-value < 0.01. The yoga warrior activity was unique in that all data relative to body weight and lean body mass had a mean MET score that was the same as the absolute data. The statistical analysis revealed that these MET scores were significantly higher than resting levels. Figure 4 shows that the mean $\dot{V}O_2$ for each exercise was higher than the standardized and measured RMR means. All other activities were significantly higher than resting MET level of 1, using absolute, relative to body mass and relative to lean body mass data, with t values ranging from 15.533 for the yoga warrior to 23.966 for the aerobics basic run long, degrees of freedom = 24, p< 0.01.

Hypothesis 2

A set of one sample t-tests was conducted to compare the intensity levels of selected Wii Fit exercises to the moderate intense physical activity threshold of 3 MET as defined by ACSM. Refer to Tables 5-8 for a synopsis of the activities MET scores and

$\dot{V}O_2$. Figure 3 shows that the strength and aerobics activities mean MET level was higher than 3 MET threshold for moderate intensity physical activity, while the yoga activities mean MET was lower than 3 MET. The activities that were significantly higher in both measured MET data and calculated MET data were the aerobics basic run easy and medium. The aerobics basic run easy activity had t values ranging from 8.060 for the measured MET score relative to LBM to 11.246 for the calculated absolute MET score, with degrees of freedom = 24, $p < 0.01$. The aerobics basic run medium activity had t values ranging from 10.032 for the measured MET score relative to LBM to 14.370 for the calculated MET relative to LBM, with degrees of freedom =24, $p < 0.01$.

The calculated MET values were significantly higher for both of the Strength exercises (single leg extension and lunges) when compared to the 3 MET moderate intensity threshold recommended by the ACSM (1, 3, 4, 33). Refer to Tables 5-8 for a synopsis of the activities MET scores and $\dot{V}O_2$. The calculated MET for the strength single leg extension activity had t values ranging from 4.022 for the calculated MET score relative to LBM to 4.081 for the calculated absolute MET score, with degrees of freedom= 24, $p < 0.01$. The calculated METs for the strength lunge activity had t values ranging from 3.605 for the calculated MET score relative to body mass to 3.312 for the calculated absolute MET score, with degrees of freedom= 24, $p < 0.01$. The strength activities measured MET intensity were the same as the 3 MET moderate intensity threshold. The measured METs for the strength single leg extension activity had t values ranging from 2.0 for the measured MET score relative to LBM to 2.1 for the measured absolute MET score, with degrees of freedom= 24, p ranged from 0.05 to 0.057. The measured METs for the strength lunge activity had t values ranging from 1.5 for the measured absolute MET score to 1.9 for the measured MET score relative to LBM, with degrees of freedom= 24, p ranged from 0.073 to 0.15.

The measured and calculated MET values for each Yoga activity were significantly lower than the moderate intensity exercise MET threshold of 3. Refer to Tables 5-8 for a synopsis of the activities MET scores and $\dot{V}O_2$. The yoga chair activity had a significantly higher MET score than the Warrior exercise, t (24) = -3.227, p< 0.01. The yoga chair activity was significantly lower than the 3 MET in both measured and calculated MET scores. The t values ranged from -3.3 for the calculated absolute MET score to -6.8 for the measured absolute MET score, with degrees of freedom= 24, p< 0.01. The Warrior exercises had lower mean MET scores than the Chair activity and were also significantly lower than the moderate intensity exercise level of 3 METs. The t ranged from -7.383 for the calculated MET relative to LBM to -3.871 for all measured MET scores, with degrees of freedom= 24, p< 0.01.

Hypothesis 3

A set of paired sample t-tests was run to determine if the intensities between medium difficulty activities and easy difficulty level activities were statistically different. Refer to Tables 5-8 for a synopsis of the activities MET scores and $\dot{V}O_2$. The two exercise types that had different difficulty levels were the strength and aerobic activities. The results of the statistical analysis indicate that the selected medium difficulty aerobic activity (5.7 ± 1.34) was significantly more intense than the easy difficulty aerobic activity (5.0 ± 1.22), t ranged from -4.8 for the measured MET relative to LBM to -5.1 for the calculated absolute MET value, with degrees of freedom= 24, p< 0.01. The strength activities showed no statistical difference of intensity between difficulty levels, and the more difficult single leg extensions had a mean intensity of 3.3 ± .71, and the easier lunges had a mean intensity of 3.2 ± .60. For the strength activities the t ranged from -0.27 for the calculated MET relative to LBM to -0.95 for the measured absolute MET value, with degrees of freedom= 24, p ranged from .352 for the measured absolute MET to .792 for the calculated MET relative to LBM. The yoga activities showed a statistical difference between the yoga warrior mean intensity (2.3 ± .42), and the yoga chair pose mean intensity (2.5 ± .37), but there is no difficulty rating for yoga exercises in the game. For the yoga activities the t ranged from -3.0 for the calculated MET relative to LBM to -3.2 for the measured absolute MET value, with degrees of freedom= 24, $p < .05$.

Differences between Calculated MET Intensity and Measured MET Intensity

Refer to Tables 9 and 10 for a synopsis of the activities measured and calculated MET scores. Figure 5 also provides a graphical representation of the mean MET score from standardized and measured resting metabolic rates. The measured MET values were determined by dividing the measured exercise $\dot{V}O_2$ by the measured resting metabolic rate. The calculated MET values were determined by dividing the measured activity $\dot{V}O_2$ by the standardized resting metabolic rate. The measured MET values were significantly different in five of the activities when compared to the calculated MET values. The t values ranged from -2.2 for the aerobics basic run easy activity MET relative to body mass to -2.6 for the yoga chair activity absolute MET, with degrees of freedom= 24, $p < 0.05$. The measured MET values were significantly different than the calculated MET values for both of the yoga activities and both of the strength activities. For the aerobic activities the basic run easy activity was significantly different between measured and calculated MET while the basic run medium activity did not have a significantly different measured MET score from the calculated MET score. The aerobics basic run medium activity t ranged from -2.0 for the MET relative to body mass to -2.1 for the absolute MET, with degrees of freedom= 24, p ranged from .051 to .054.

Table 9. Comparison of Wii Activity between Measured and Calculated MET Values at Medium Difficult Intensity Level

	Yoga Warrior Mean ± SD (n=25)		Aerobics Basic Run Easy Mean ± SD (n=25)		Strength Lunges Mean ± SD (n=25)	
	Measured MET	Calculated MET	Measured MET	Calculated MET	Measured MET	Calculated MET
Absolute Data (MET)	2.30 ± 0.42[a]	2.44 ± 0.38[a]	4.98 ± 1.22[a]	5.26 ± 1.00[a]	3.18 ± 0.62[a]	3.38 ± 0.57[a]
Relative to body mass (MET)	2.30 ± 0.42[a]	2.44 ± 0.38[a]	4.97 ± 1.23[a]	5.24 ± 1.00[a]	3.23 ± 0.60[a]	3.43 ± 0.60[a]
Relative to lean body mass (MET)	2.30 ± 0.42[a]	2.44 ± 0.38[a]	4.97 ± 1.23[a]	5.24 ± 1.00[a]	3.23 ± 0.60[a]	3.43 ± 0.60[a]

Note: Measured MET was determined using the measured RMR. Calculated MET was determined with the standardized RMR. Significant Statistical Results: a= different MET value when compared between measured and calculated MET for (L/min, mL/kg/min, and mL/kg LBM/min)

Table 10. Comparison of Wii Activity between Measured and Calculated MET Values at Easy Difficult Intensity Level

	Yoga Chair Mean ± SD (n=25)		Aerobics Basic Run Medium Mean ± SD (n=25)		Strength Single Leg Ex. Mean ± SD (n=25)	
	Measured MET	Calculated MET	Measured MET	Calculated MET	Measured MET	Calculated MET
Absolute Data (MET)	2.51 ± 0.36[a]	2.68 ± 0.47[a]	5.73 ± 1.36	6.04 ± 1.09	3.30 ± 0.71[a]	3.48 ± 0.59[a]
Relative to body mass (MET)	2.5 ± 0.37[a]	2.67 ± 0.48[a]	5.69 ± 1.34	6.0 ± 1.05	3.28 ± 0.71[a]	3.47 ± 0.58[a]
Relative to lean body mass (MET)	2.5 ± 0.37[a]	2.67 ± 0.48[a]	5.69 ± 1.34	5.99 ± 1.04	3.28 ± 0.71[a]	3.47 ± 0.58[a]

Note: Measured MET was determined using the measured RMR. Calculated MET was determined with the standardized RMR. Significant Statistical Results: a= different MET value when compared between measured and calculated MET for (L/min, mL/kg/min, and mL/kg LBM/min)

Correlation between Self Reported Physical Activity Level and MET Intensity

Table 11 presents correlation coefficients between MET scores for each activity and the IPAQ score of each participant. A correlation between participants self reported physical activity level from the IPAQ questionnaire and the MET intensities was run to determine if self reported physical activity level was related to the intensity level of a participant during the selected Wii Fit activities. A Pearson r correlation was calculated to determine if there was a relationship between the raw IPAQ score and any of the measured or calculated MET for each exercise. No significant correlations were found among all exercise types calculated and measured MET (absolute, relative to body mass and relative to lean body mass). The Pearson r coefficients ranged from -0.10 for the yoga warrior calculated MET relative to body mass to 0.33 for the strength lunge absolute measured MET, with the number of cases = 25 and p-values ranging from 0.102 to .986.

Table 11. Correlations between IPAQ Raw Score and MET Scores

		Yoga Warrior	Basic Run Short	Strength Lunge	Strength Single Leg Extension	Basic Run Long	Yoga Chair
		IPAQscore	IPAQscore	IPAQscore	IPAQscore	IPAQscore	IPAQscore
Absolute Measured MET	Pearson Correlation	.076	.173	.334	.116	.157	.176
	Sig. (2-tailed)	.716	.408	.102	.580	.454	.399
Measured MET relative to BM	Pearson Correlation	.076	.174	.332	.119	.164	.177
	Sig. (2-tailed)	.716	.406	.105	.570	.432	.398
Measured MET relative to LBM	Pearson Correlation	.076	.174	.332	.119	.164	.177
	Sig. (2-tailed)	.716	.406	.105	.570	.432	.398
Absolute Calculated MET	Pearson Correlation	-.091	.069	.213	.004	.050	-.037
	Sig. (2-tailed)	.665	.743	.306	.986	.812	.860
Calculated MET relative to BM	Pearson Correlation	-.103	.061	.173	-.007	.050	-.045
	Sig. (2-tailed)	.623	.771	.408	.975	.814	.832
Calculated MET relative to LBM	Pearson Correlation	-.091	.071	.186	.008	.061	-.033
	Sig. (2-tailed)	.665	.735	.373	.969	.771	.876

Notes: Measured MET was determined using the measured RMR. Calculated MET was determined with the standardized RMR. IPAQ score refers to the raw score from the IPAQ questionnaire (MET-min/week). Statistical significance is = a.

CHAPTER 5

DISCUSSION

Physical activity is an essential component to a healthy lifestyle and should be a part of everyday life in all individuals. The continued development of physical activity interventions to combat decreasing physical activity levels throughout all age ranges, is essential to reversing the trend of decreased physical activity participation [6, 8, 11-13, 16]. The benefits of physical activity to the health and wellness of individuals are well documented in research [6].

Video game popularity contrary to physical activity seems to be increasing every year and technology has advanced enough to allow for exercise themed home video games to be developed [31]. The accessibility of the Nintendo Wii® for use at home, in addition to the fun nature of the game provide a potential platform for physical activity intervention. It is important for physical activity interventions to continue development looking for new tools and platforms for physical activity prescription. Unfortunately, many of these platforms such as active video games consoles have not been extensively researched [11, 17]. The determination of the intensity level of these exercises themed games are important to understanding the potential of these systems. Such information will allow experts to determine if these exercise themed games meet the guidelines for physical activity recommended by ACSM.

Major Findings

The most important findings from this study were that selected Wii Fit activities $\dot{V}O_2$ were significantly higher than resting $\dot{V}O_2$ levels. The hypothesis that selected Nintendo Wii Fit® fitness activities would not meet the ACSM guidelines for moderate intensity physical activity was rejected and some of the activities did meet the moderate intensity guidelines. The yoga themed exercises were significantly lower than the ASCM physical activity threshold for moderate intensity exercise. The strength exercises were either the same or statistically significantly higher than the ACSM threshold for moderate intensity exercise. The aerobic themed exercises were all significantly higher than the ACSM physical activity threshold for moderate intensity exercise. The hypothesis that the $\dot{V}O_2$ of medium difficulty Wii Fit exercises would be greater than easy difficulty level exercises was inconclusive. The medium difficulty level aerobic activity was significantly more intense than the easier aerobic activity. No statistical difference in intensity level was found between the two strength exercises. The yoga exercises were significantly different from each other but there is no stated difficulty level to any of the yoga exercises.

That the measured resting metabolic rates were significantly higher than the standardized RMR (3.5 mL/kg/min), which resulted in lower MET intensities when using measured RMR data. In addition, the measured MET values were significantly lower than the calculated MET values in all activities except the basic run long. Therefore, the measured MET values were directly affected by the higher measured resting metabolic rate, which may in turn be influenced by the body composition of the participants of the study. With a higher resting metabolic rate in the MET equation, the resulting intensity would be lower than the intensity calculated from the standardized RMR of 3.5 mL/kg/min. The characteristics of the study participants indicate a highly active population which could explain the higher measured RMR values. Populations that are more active typically have higher resting metabolic rates than individuals that are the same mass but less active [1]. A potential reason for this is that a more active population will have a greater amount of lean body mass. Theoretically, the more lean tissue an individual has the more oxygen that will be required to maintain that tissue.

Comparison of Selected Activity Intensity to Resting Intensity Level

When someone is at rest, the MET intensity level is said to be one because the amount of energy being expended is equal to RMR. This study found that all of the selected Wii Fit activities had an intensity level that was significantly higher than resting intensity levels. These results are consistent with other video game research that has found traditional video games require more energy than resting levels and that active video games require significantly more energy than traditional video games [19, 25, 90]. It is important that all the selected activities required more $\dot{V}O_2$ than resting levels because the definition of physical activity is any bodily movement that requires energy expenditure about resting levels [1]. However, during the development of this study, some activities on the Nintendo Wii Fit® were not selected because of the perceived low intensity levels of these activities including the Lotus Focus and Deep Breathing activities. These activities essentially required the participant to stand or sit on the balance board and breathe deeply. The activities that were selected represented a basic broad compilation of activities that most individuals would put into a basic exercise routine. Therefore, it was important to determine that the activities intensity was significantly above resting levels to verify the potential for the Nintendo Wii® to be used as a physical activity tool.

Meeting the Moderate Intensity Activity Threshold

The moderate intensity physical activity threshold guidelines from ACSM are important because they provide is the level at which significant health benefits and physical fitness improvement occurs. Lower intensity exercises, while beneficial, do not provide the same significant amount of health benefit [1, 3, 4, 37]. This study examined the intensity levels of six selected Wii Fit exercises in three exercise classifications including strength, yoga and aerobics. To determine the intensity levels of these exercises, $\dot{V}O_2$ was measured by indirect calorimetry during exercise and at rest. Determining mean oxygen consumption during an activity allowed for the calculation of metabolic equivalents which are used to quantify exercise intensity. For this study, both measured and predicted resting metabolic rates in L/min, mL/kg/min, and mL/kg LBM/min were used to examine the MET calculation absolutely and relative to body mass and LBM.

The aerobics styled exercises (Basic Run Easy, Basic Run Medium) were significantly higher than the ACSM guidelines for moderate intensity exercise using both the predicted and measured resting metabolic rate. These aerobic type exercises met the intensity component of the ACSM guidelines, but both exercises failed to reach the minimum duration of ten minutes for bouts of physical activity [3, 4, 37]. This study is the first to examine the intensity levels of the selected Wii Fit activities, but the results are promising given that the strength and aerobic activities can generate a moderate intensity level in an active population of both males and females. The minimum amount of time between exercise activities to just repeat the same activity is 30 seconds allowing the body to recovery significantly before continuing the workout. If the activity was changed for example, from a yoga exercise to a strength exercise, the average amount of time between these two activities was over one minute in duration. This has implications for the individuals who design these programs in the future because of the control they have on future game design.

The strength exercises had significantly higher calculated MET values compared to the ACSM guidelines for moderate intensity exercise and, the measured MET values had no statistical difference compared to the moderate intensity threshold of 3 METs. The current recommendations on strength training from the ACSM simply indicate that strength training should be done twice a week and include all major muscle groups; no intensity or duration components were associated with strength training [3, 4, 37]. Newer versions of the game could be easily modified to increase the duration of exercises by allowing for activities to be played back to back. Additionally, the game spends a lot of time post activity providing feedback and a score for the activity. This portion could easily be moved to the end of a set of activities to increase the constant exercise duration.

The yoga exercises on the other hand resulted in an intensity level that was significantly lower than the ACSM guideline for moderate intensity. Even though these activities did not generate the intensity level required to meet the moderate intensity physical activity guidelines, the yoga exercises will help to improve flexibility and balance which are important component of physical fitness. Other populations, which are not as active as this study's population might have a higher intensity level for the yoga poses, which could then possibly meet the ACSM moderate intensity guidelines. The yoga poses that were selected were more of the basic poses to ensure that all participants would be able to complete the pose, but the game does have much more difficult poses which theoretically could have generated 3 MET or higher intensity scores.

Overall, these results indicate a significant amount of promise for the Nintendo Wii® system as a physical activity tool and as an intervention. Unfortunately, the current edition of the game is limited in its ability to link exercises to increase the continuous duration of activity. Other studies have examined active video game systems and have found that these systems can meet the ACSM guidelines for minimum activity, but no studies have been done examining an exercise themed game [19-21, 24]. These other studies which have used populations ranging from children to college aged individuals indicate that active video games do generate significantly more energy expenditure than traditional systems.

The promise of the Nintendo Wii Fit® system for use with different populations is good because of the characteristics of this study's population. As previously stated, the population of this study was a very fit and active population. Typically, physically active and fit populations are more efficient and expend less energy than a less fit person does during the same exercise [1]. Although, the active population of this study is more familiar with these exercise techniques and might perform activities properly as opposed to a child who might not fully understand the instructions. As these systems continue to develop, fitness games need to be careful of the game design to ensure that a child could complete an activity with the instructions given.

Intensity Differences between Activity Difficulty Levels

Any exercise program would not be complete unless the program participant had the ability to increase the workload to prevent training plateaus from being reached [1, 38].

Therefore, with the Nintendo Wii Fit®, it was important to determine if exercise activity difficulty development would result in a progression of intensity. Many of the exercises in the strength, aerobics and balance categories had three options for increasing the difficulty through for example the addition of more repetitions in the strength exercises. This study examined only the easy and medium difficulty level exercises. Theoretically, the intensity would increase for the hard level exercises compared to the medium exercises. This would allow the hard difficulty exercises to meet a moderate intensity bout of exercises according to the ACSM.

The aerobic activity (Basic Run) difficulty levels resulted in a significantly higher intensity level when comparing the long run to the short run. The running speed of the participant was subjective and they could speed up or slow down at their own choosing, however the participants all finished at roughly the same amount of time. The yoga exercises also had a significant difference in intensity between the two activities. Wii Fit does not have a difficulty ranking for yoga poses. These results indicate that it is possible for an individual to customize a workout and allow for an increased intensity following a training effect. A training effect occurs after each workout, in that the muscles and cardiovascular system adapt to more easily complete that same activity in the future.

The strength exercises did not have a significant difference in intensity level between difficulty levels. Although, two different strength exercises were used, one was set on the medium number of repetitions and the other was set to easy. Strength exercises are not included in the ACSM guidelines under moderate intensity because those guidelines are written for aerobic exercise [3, 4, 37]. The ACSM does recommend some sort of weight training twice a week using all major muscle groups, and based on the results of the study the participants were expending energy while training some of the major muscle groups (hamstrings, quads, abdominals) with the selected strength activities [3, 4, 37]. The Nintendo Wii® uses body weight as the primary resistance for the different strength themed exercises. The game does show and describe the activity in layman's terms to help the user understand how to complete each activity, but these instructions are often not detailed enough and many participants had a significant learning curve during the Wii familiarity session.

Wii Fit Game Design

Throughout the data collection process many observations were made by the principle researcher and the research assistants. First, the shortest amount of time between two exercises was 30 seconds. The activity demonstrations were very basic and did not always provide enough insight for a lay person to understand appropriately. The amount of effort that a participant put forth seemed to vary slightly based on technique and form choice which are subjective to the participant. The game could not differentiate between someone who was doing an exercise with proper technique and someone who was not. The running exercise was limited in how fast a participant could run in place. Finally, during the running exercises there were issues with controller sensitivity (e.g., the controller would not properly read every participant step.)

While the potential benefits of the Nintendo Wii® have been established from the hard data provided earlier, the principal investigator did observe some information that is prudent to consider when examining the Nintendo Wii Fit® game as a physical activity tool. Foremost is the amount of effort that participants put forth during Wii Fit activities, in an uncontrolled setting (out of the supervision) participants may not try as hard. The experience level of the participants in this study eliminates effort variability between participants who completed the exercises using proper form and technique. In an uncontrolled environment such as the home, the amount of effort that someone puts into the game is completely subjective. For example, two different people could do the Lunge exercise and one individual properly goes all the way down while the other individual just goes far enough to complete the exercise. Clearly, the individual who completes the exercises appropriately by going all of the way through the range of motion would be working harder and receiving additional benefits. For this tool to be a successful physical activity intervention modality in a non supervised setting, individuals would need to hold themselves accountable and be familiar with the exercise techniques.

Secondly, at the conclusion of each activity, the Wii Fit provides a score and label based on the participants' performance during the exercise. The first issue that was noticed with these scores was that a trained individual who has done a certain exercise before such as a rowing squat, may have perfect form but the game gives them a below average score and label. In contrast, someone could complete that same exercise incorrectly and the game may give them a near maximal score. As an example, all participants completed the lunges using appropriate form and technique, yet scores ranged from low to high.

Another issue is that the labels in the scoring system such as "couch potato" or "yoga master" could result in negative reinforcement for the participant. The individual who gets a "couch potato" ranking may begin to feel less motivated about working out. To the contrary, someone who gets labeled a "yoga master" may not have any yoga experience but may think that they are ready to try the more advanced yoga poses, which could lead to injury. The one way that Nintendo has partially prevented this from occurring is that the more difficult activities are "locked" on the game initially and need to be unlocked by successfully completing easier activities multiple times.

A fourth issue is that the instructions that are provided before certain activities are too condensed. The game attempts to briefly show and demonstrate an activity prior to the participant beginning that activity. Nintendo had a good idea in showing the participants what to do, but not all steps are fully explained. Unknowingly, individuals could complete activities incorrectly according to their view of the instructions. Additionally, instruction was provided by the investigator prior to the onset of each activity to ensure proper form and technique of each exercise. Without this additional instruction, individuals might incorrectly perform some of the activities. This level of questioning the instruction occurred in a fairly active and fitness-knowledgeable population. The results may have been somewhat different in a group of individuals with less fitness experience, or without any supervision or additional instruction.

Finally, the game has many informative components such as BMI calculation/ explanation and tracking of personal data such as workout summaries, weight over time, and BMI over time. The game automatically logs activity level, weight and BMI, without the need to do anything additional other than play the game, which is an extremely useful tool for someone to look back at trends during specific time periods. The ability for an individual to track training, weight and BMI over extended periods of time allows individuals to better understand activity habits, and possibly understand reasons for lack of activity on certain days.

The animations used in the game also differ significantly between exercise types. A cartoon looking self-image based on individual information such as height and weight is used for the balance and aerobics exercises. The strength and yoga exercises utilize a fairly realistic looking human trainer to demonstrate and follow during activity. Nintendo Wii Fit® seems to be trying to make the game marketable to adults and kids through these two animation types. If the game was more intent on being a fun way to be active, the small cartoon looking self-image should be used in all exercises. By switching back and forth between a trainer and the cartoon, some individuals might be more inclined to play the more fun cartoon oriented games then the serious trainer led activities.

Limitations of the Testing Protocol

This study was limited in some of the assumptions that were made to allow for protocols to be followed according to the validated methods. The measurement of the resting metabolic rate was one of the protocols that required assumptions about the participants' adherence to the protocol. In preparation for measuring resting metabolic rate, participants were instructed to fast for 12 hours prior to the test and refrain from vigorous physical activity 24 hours prior to testing [88]. There was no way for the primary investigator to enforce these instructions; therefore it was assumed that participants followed the instructions. If participants didn't follow these recommendations, differences could occur between measured resting metabolic rate and actual metabolic rate.

In an attempt to limit variability in Wii Fit motor task efficiency, participants were restricted to no more than ten Wii Fit playing sessions. It was assumed that participants in the study answered this question honestly. The amount of previous experience on the Wii Fit was limited so that all participants would have similar backgrounds, learning curves and variability due to familiarity.

The Nintendo Wii Fit® has more than 48 activities, some with multiple difficulty levels, available to the player once the game has been fully unlocked. For the purpose of participant retention, only six activities were selected for use in this study. Since all activities were not measured, data supported conclusions for each exercise cannot be made. Additionally, no balance activities were selected as part of the study due to the perceived extremely low impact level of these activities compared to the other three categories. The goal was to get a representation of the capabilities of the Nintendo Wii® system and the Wii Fit game as a physical activity intervention tool.

Due to the characteristics of the sample tested in this study, the ability to generalize the results of this study is limited until further research can be completed. The study also contained a high proportion of women compared to men, which made it difficult to compare intensities between genders. Additionally, the weight threshold of 300 pounds placed on the Nintendo Wii® Balance Board minimizes the potential of the Nintendo Wii® to be an activity tool in obese individuals over 300 pounds.

Implications of Findings

The results of this study are interesting in that the potential of the Nintendo Wii Fit® game to be a beneficial physical activity tool is partially shown. The moderate intensity threshold of 3 MET developed by the ACSM is a very important threshold for physical activity. The fact that some of the Wii exercises could meet or exceed this threshold holds excellent promise for future use of the Wii as a tool for physical activity, especially in the currently sedentary population. The activity intensity level is the most crucial component of the ACSM guidelines because an individual can easily regulate frequency and duration by playing more than one game, multiple days a week. Furthermore, the Nintendo Wii® is a very widespread piece of technology in America and worldwide, indicating a means for implementing physical activity interventions on a widespread scale [18].

Further game development is required to turn the Nintendo Wii Fit® franchise into a self-supervised physical activity tool that could be recommended in place of traditional physical activity. The ability to pre-program a continuous extended workout would be one of the most advantageous changes to enhancing this game. By allowing the player to pre-determine an activity bout with multiple different activities including changes to intensity, duration, and frequency, there would be less time between activities which would help the player maintain activity over a longer duration of time. The game could also benefit from moving directly from one activity to the next when using the pre-programmed exercise. Furthermore, slight modifications to the activity demonstrations would be beneficial. Bringing in exercise professionals could help the games to better develop the wording used to verbally describe an exercise. It would also be nice to have more accurate representations of the exercises shown by the “trainers.” Using a motion tracking system on an exercise professional conducting all of the exercises might provide a more realistic representation of the activity.

Recommendations for Future Research

This study was unique in its examination of the Wii Fit activity intensity levels, but it was another step in continuing research on the potential use of video game technology as a physical activity tool. Additional research would be beneficial to paint a more detailed picture of the exact capabilities of the Nintendo Wii® system and the Nintendo Wii Fit® game. First, since the onset of this study, a second updated version of the Nintendo Wii Fit® game has been released, so future research studies could examine the difference between these two versions of the game. There are also other fitness game franchises that are available on the Nintendo Wii® system, and it would be interesting to see the differences and potential of these games, some of which use the Wii Balance Board as well.

For the Wii Fit game itself, further research needs to be conducted on the rest of the activities to determine which exercises are the most intense and which activities have little benefit. Research in other populations to determine the intensity level of the system would also be beneficial as the Nintendo Wii® is used with children as a PE alternative and in elderly individuals for balance improvement. Another potential research topic would be to determine the effectiveness of the Wii Fit activity demonstrations to see how that affects intensity and exercise form. The determination of the games ability to improve physical fitness and progress an individual to allow for continued training would establish the ability of the Wii to act as a standalone physical activity platform.

Conclusion

In conclusion, the selected activities from the Nintendo Wii Fit® game were significantly higher than resting intensity levels. The results of the study indicate that some of the activities, specifically the strength and aerobics styled exercises met or exceeded the moderate intensity threshold developed by the ACSM. The results of the study also showed that some of the medium difficulty activities had a significantly higher intensity level compared to the easy difficulty, which indicates the games ability to progress intensity level as fitness adaptations occur. Finally, based on the results of the study, the potential benefit of the Nintendo Wii Fit® game and the Nintendo Wii® system to become a satisfactory physical activity tool is encouraging, especially with slight modifications. Due to the popularity of video games and the Nintendo Wii® system, these findings will allow for the further advancement of exercise themed video games to become physical activity intervention platforms in the future.

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APPENDIX A

Medical Information Form

Medical Information Form
BSU Department of Kinesiology

Name: ____
Address: ____
City & State: _______________________________________
Phone Numbers: ____________________________________
Email Address: _____________________________________
Date of Birth ________________ Sex ______

Emergency Contact (Name/Phone #): ____

Insurance: Each person is responsible for their own personal medical expenses. For your personal financial protection, sickness and accident insurance is recommended.

Medical Information (your information will remain confidential): In the space provided below, please indicate whether you are on medications, have any allergies to food, bee stings, or ragweed, or have any reactions to medications. Also indicate any medical condition that might require modifying your exercise program or prevent you from safely participating in exercise.

Please circle "YES" or "NO" and provide additional details where requested on all three sides of this form.
Do you take any prescribed medication on a permanent or semi-permanent basis (steroids, anti-inflammatories, antibiotics, insulin, etc.)?
NO YES (list and give reason)

____

2. Do you take any metabolic medications on a permanent or semi-permanent basis (diet pills, beta blockers, caffeine pills, etc.)?
NO YES (list and give reason)

____

3. Have you ever had an epileptic seizure?
NO YES

4. Have you ever been told by a doctor that you have epilepsy?
NO YES (list any medication)

____

5. Have you ever been treated for diabetes?
NO YES (list any medication)

____

6. Have you ever been told by a doctor that you were anemic?

NO YES When? ____________________ What treatment? __________________

7. Have you ever been told by a doctor that you have sickle cell anemia?
NO YES

8. Do you have or have you ever had high blood pressure?
NO YES (list any medication)
____

9. Have you ever been told by a doctor that you have asthma?
NO YES (list any medication)
____

10. Do you have or have you ever had a hernia or "rupture"?
NO YES (if so, has it been repaired?)
____

11. Do you wear glasses or contacts during competition?
No YES

12. Do you wear any of the following dental appliances:
NO YES (Circle those that apply)
Permanent bridge Braces Removable retainer Permanent retainer
Removable partial plate Full plate Permanent crown or jacket

13. Have you had a broken bone (fracture) in the past two years?
NO YES
What bone? _____________________ right or left? ____________ Dates ________

14. Have you had a shoulder injury in the past two years that disabled you for a week or longer (dislocation, separation, etc.)?
NO YES
Type of injury _____________________ right or left? _________ Dates ___________

15. Have you ever had shoulder surgery?
NO YES What was done and why?
____
right or left? _____________ Dates _______________

16. Have you ever injured your back?
NO YES Type of injury _________________________________ Date (s)

17. Do you have back pain?
NO YES (Circle any that apply)
Seldom Occasionally Frequently With Vigorous Exercise With Heavy Lifting

18. Have you injured your knee in the past two years?
NO YES

19. Have you been told by a doctor or athletic trainer that you injured the cartilage in your knee?
NO YES right or left? ________ Date(s) ________
20. Have you ever had knee surgery?
NO YES What was done and why? ___________________________________
Right or left? __________ Date(s) _________
21. Have you had a severe ankle sprain in the past two years?
NO YES
22. Do you have a pin, screw, or plate in your body?
NO YES
Where in your body? ____________________________________ Date(s) _____
23. Do you have any other conditions that we should be aware of (i.e., ulcers, pregnancy, food or insect allergies, tendonitis, etc.)?
NO YES (Specify and give details)

Permission for Medical Care. Please read carefully and sign in the space provided. Consent is given for the signee to participate in this dryland hockey conditioning program. Permission is given for any emergency anesthesia, operation, hospitalization, or other treatment that might become necessary. You should know that many participants with a variety of medical/psychological difficulties have successfully completed similar programs over the years, but we must be aware of these conditions. Failure to disclose such information could result in serious harm to you and your fellow participants. If you are unable to physically participate in this program because of a pre-existing condition that was not indicated on this medical form, we cannot help you modify your participation appropriately and we may be limited in the help we can provide in an emergency situation. Please be honest so we can help accommodate your needs and develop a safe and effective conditioning program for everyone.

The questions on this form have been answered completely and truthfully to the best of my knowledge.

Signature of Participant Date

APPENDIX B

Truemax 2400 Calibration

Gas calibration for the Parvo Medics TrueMax 2400 system (perform prior to each test)

- From main menu, click on **Gas Calibration**
- Click **OK**
- Turn black plastic valve wrench on calibration gas cylinder (on right front corner of cart) counterclockwise 90°, then click **OK**
- Allow gas calibration procedure to finish, and when prompted, click **OK**
- Return valve wrench on calibration gas cylinder to original position (turn clockwise 90°)
- Click on **Save** to confirm updated gas calibration parameters

Flowmeter calibration (perform only twice daily)

- Attach one end of the short (2 ft) blue hose to the 3-L calibration syringe and the other end to the left port of the mixing chamber at the back of the cart
- From main menu, click on **Flowmeter Calibration**
- Click on **Sample Baseline**
- When prompted, deliver 10 complete strokes at various flow rates (only the last 5 are used for the calibration)
- Click on **Save** to confirm flowmeter calibration parameters

Performing metabolic (VO_2) measurements

- From main menu, click on **Metabolic Measurement**
- Within *Patient Information* screen, provide requested information; click **OK** when finished
- Click **OK** to automatically sample base-line ambient air; click **OK** after sample for at least 10 s
  - When ready to begin testing, click **OK** Before beginning test, properly adjust subject's head gear and nose clip If, measuring HR, fit subject with HR transmitter and attach HR monitor from cart to Velcro strip on handrail of the treadmill
- To pause data collection during a test, click on **Pause**; click **Resume** to begin collecting data again
- To end the test, click **End Test**, and when prompted to save the data, click **OK**

APPENDIX C

Equipment Photos


Wii
Wii


POLAR
LIGHT
Thu 22
OK
BACK
9:59 pm 18
POLAR

APPENDIX D

IRB Informed Consent Form

CONSENT TO BE A RESEARCH PARTICIPANT
BOISE STATE UNIVERSITY

A. PURPOSE AND BACKGROUND

Josh Grieser, B.S., Yong Gao, Ph.D., in the Department of Kinesiology at Boise State University are conducting a research study titled "COMPARING THE ENERGY EXPENDITURE WHILST PLAYING THE NINTENDO WII: WII FIT IN TRAINED AND UNTRAINED COLLEGE STUDENTS ." The purpose of this study is to determine the energy expenditure cost of play Nintendo Wii Fit and determine the relative intensity level.

B. PROCEDURES

If you agree to be in the study, the following will occur:

1. You will complete various forms that will determine whether you are eligible to participate (e.g., the PAR-Q or Physical Activity Readiness Questionnaire, IPAQ or International Physical Activity Questionnaire, a medical information form, and a liability release form).

2. If you are selected to participate in this study, you will be asked to come to the Boise State Kinesiology Building for an initial data Session. During the session height, weight, and body composition (predicted body fat percentage) will be measured prior to exercise. You will then be asked to do a resting metabolic rate using a metabolic cart, this will measure how much energy you are expending at rest.

5. You will be asked to come to the Boise State Kinesiology Building for a two Wii Fit exercise sessions. During the exercise protocol you will be asked to complete a 30 minute predesigned workout on the Nintendo Wii console. During the exercise you will be wearing a polar heart rate monitor and hooked up to the metabolic cart. Three different exercises will be completed during each Wii testing session. Exercise difficulties will include low or moderate and exercise types will include strength, endurance and yoga.

The Wii training session will be completed in the Human Performance Lab (rm. 119) in the Kinesiology Building at Boise State University.

C. RISKS/DISCOMFORTS

1. Due to the submax nature of the program design the risks involved are minimal in this research study. There are no risks associated with questionnaire completion as all data will be kept confidential and under lock and key at all times. Slight discomfort can occur during the measurement of skin-folds for body composition prediction. Additionally some slight discomfort may be seen while connected to the metabolic cart, some individuals dislike the mouth pieces and being connected to a machine while breathing.

2. As with any physical activity and exercise there are risks involved, that includes injury (such as sprains or strains), overexertion, heart abnormalities, shortness of breath, and a temporary increase in systolic blood pressure.

3. To minimize risk of injury during exercise, or physical activity, the following precautions will be taken:
    a) A five minute walking warm up at a self selected speed before each Wii Fit exercise session.
    b) Between each exercise type a rest period will be given
    c) Following the completion of the Wii Fit exercise protocol a cool down will be completed
    d) All exercises sessions will be supervised by experienced, trained individuals from Boise State University
    e) Participants will be remained throughout the exercise session to stop participation immediately if pain or discomfort is too much, they feel dizzy, and nauseous
4. Confidentiality will be protected for all data collected throughout the study. Physical data such as consent forms, questionnaires will be kept in a locked file cabinet inside the Human Performance Laboratory. Electronic data will be stored on a password protected computer inside the Human Performance Laboratory. All indentifying information will be removed from data to increase protection; participants will be given a code that will be used to identify un-coded data. The code sheet will be stored on a USB flash drive that will be stored with the physical data in the locked file cabinet. Only Josh Grieser, Dr. Shawn Simonson, and Dr. Yong Gao will have access to the study data. Individual identities or identifying information will be used in any publications of this study.

D. <u>BENEFITS</u>

The main benefit to participating in this study is that you may find that you enjoy playing Wii Fit or already play Wii Fit and may want to know more about the potential benefits it could provide as a physical activity tool. Boise State students will also learn a great deal about research participation and data collection by participation in this study. You will help the primary investigator to complete the thesis requirement for his Masters degree.

E. COSTS

There will be no monetary costs associated with participation in this study. Although travel and time requirements will occur.

F. PAYMENT

You will NOT be paid to participate in this study.

G. QUESTIONS

Due to the make-up of Idaho's population, the combined answers to questionnaires may make an individual person identifiable. We will make every effort to protect participants' confidentiality. However, if you are uncomfortable answering any of these questions you may leave them blank.

If you have any questions or concerns about participation in this study, you should first talk with the Primary Investigator (Josh Grieser M.S. is available at 426-5518 or at joshuagrieser@u.boisestate.edu) or the co- Primary Investigator (Yong Gao, Ph.D., is available at yonggao@boisestate.edu.) If for some reason you do not wish to do this, you may contact the Institutional Review Board, which is concerned with the protection of volunteers in research projects. You may reach the board office between 8:00 AM and 5:00 PM, Monday through Friday, by calling (208) 426-5401 or by writing: Institutional Review Board, Office of Research Compliance, Boise State University, 1910 University Dr., Boise, ID 83725-1138.

Should you feel discomfort due to participation in this research and you are a BSU student, you may contact the Boise State University Health and Wellness Center for counseling services at (208) 426-1601. If you are not a BSU student and you feel discomfort, you should contact your own health care provider.

H. CONSENT

You will be given a copy of this consent form to keep.

PARTICIPATION IN RESEARCH IS VOLUNTARY. You are free to decline to be in this study, or to withdraw from it at any point. Your decision as to whether or not to participate in this study will have no influence on you present or future status

I give my consent to participate in this study:

____ ____________________

Signature of Study Participant Date

I give my consent to use any photographs of me from this study:

____ ____________________

Signature of Study Participant Date

____ ____________________

Signature of Person Obtaining Consent Date

THE BOISE STATE UNIVERSITY INTSTITUTIONAL REVIEW BOARD HAS REVIEWED THIS PROJECT FOR THE PROTECTION OF HUMAN PARTICPANTS IN RESEARCH.

APPENDIX E

Physical Activity Readiness Questionnaire

PAR-Q

The PAR-Q is a PDF document that can be viewed and downloaded from the Canadian Society for Exercise Physiology. The PAR-Q document can be obtained at:

http://www.csep.ca/CMFiles/publications/parq/par-q.pdf. (Retrieved: 5/9/2009).

A downloaded version of the PAR-Q as it appears in the PDF file from the above web address will be printed and given to participants to for pre-participation screening.

APPENDIX F

International Physical Activity Questionnaire

International Physical Activity Questionnaire

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE
(October 2002)
LONG LAST 7 DAYS SELF-ADMINISTERED FORMAT
FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health–related physical activity.

Background on IPAQ
The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ
Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation
Translation from English is encouraged to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

Further Developments of IPAQ
International collaboration on IPAQ is on-going and an ***International Physical Activity Prevalence Study*** is in progress. For further information see the IPAQ website.

More Information
More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). *Assessment of Physical Activity: An International Perspective.* Research Quarterly for Exercise and Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** and **moderate** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

PART 1: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?

☐ Yes

☐ No → ***Skip to PART 2: TRANSPORTATION***

The next questions are about all the physical activity you did in the **last 7 days** as part of your paid or unpaid work. This does not include traveling to and from work.

2. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, heavy construction, or climbing up stairs **as part of your work**? Think about only those physical activities that you did for at least 10 minutes at a time.

_____ **days per week**

☐ No vigorous job-related physical activity → ***Skip to question 4***

3. How much time did you usually spend on one of those days doing **vigorous** physical activities as part of your work?

_____ **hours per day**

_____ **minutes per day**

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads **as part of your work**? Please do not include walking.

_____ **days per week**

☐ No moderate job-related physical activity → ***Skip to question 6***

5. How much time did you usually spend on one of those days doing **moderate** physical activities as part of your work?

_____ **hours per day**

_____ **minutes per day**

6. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **as part of your work**? Please do not count any walking you did to travel to or from work.

_____ **days per week**

☐ No job-related walking → ***Skip to PART 2: TRANSPORTATION***

7. How much time did you usually spend on one of those days **walking** as part of your work?

_____ **hours per day**

_____ **minutes per day**

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

8. During the **last 7 days**, on how many days did you **travel in a motor vehicle** like a train, bus, car, or tram?

_____ **days per week**

☐

No traveling in a motor vehicle → ***Skip to question 10***

9. How much time did you usually spend on one of those days **traveling** in a train, bus, car, tram, or other kind of motor vehicle?

_____ **hours per day**

_____ **minutes per day**

Now think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No bicycling from place to place → ***Skip to question 12***

11. How much time did you usually spend on one of those days to **bicycle** from place to place?

_____ **hours per day**

_____ **minutes per day**

12. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No walking from place to place → ***Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY***

13. How much time did you usually spend on one of those days *walking* ***from place to place?***

_____ **hours per day**

_____ **minutes per day**

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the last 7 days **in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.**

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, shoveling snow, or digging **in the garden or yard**?

_____ **days per week**

☐ No vigorous activity in garden or yard → ***Skip to question 16***

15. How much time did you usually spend on one of those days doing **vigorous** physical activities in the garden or yard?

_____ **hours per day**

_____ **minutes per day**

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, sweeping, washing windows, and raking **in the garden or yard**?

_____ **days per week**

☐ No moderate activity in garden or yard → ***Skip to question 18***

17. How much time did you usually spend on one of those days doing **moderate** physical activities in the garden or yard?

_____ **hours per day**

_____ **minutes per day**

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, washing windows, scrubbing floors and sweeping **inside your home**?

_____ **days per week**

☐ No moderate activity inside home → ***Skip to PART 4: RECREATION, SPORT AND LEISURE-TIME PHYSICAL ACTIVITY***

19. How much time did you usually spend on one of those days doing **moderate** physical activities inside your home?

_____ **hours per day**

_____ **minutes per day**

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **in your leisure time**?

_____ **days per week**

☐ No walking in leisure time → ***Skip to question 22***

21. How much time did you usually spend on one of those days **walking** in your leisure time?

_____ **hours per day**

_____ **minutes per day**

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like aerobics, running, fast bicycling, or fast swimming **in your leisure time**?

_____ **days per week**

☐ No vigorous activity in leisure time → ***Skip to question 24***

23. How much time did you usually spend on one of those days doing **vigorous** physical activities in your leisure time?

_____ **hours per day**

_____ **minutes per day**

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis **in your leisure time**?

_____ **days per week**

☐ No moderate activity in leisure time → ***Skip to PART 5: TIME SPENT SITTING***

25. How much time did you usually spend on one of those days doing **moderate** physical activities in your leisure time?

_____ **hours per day**

_____ **minutes per day**

PART 5: TIME SPENT SITTING

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekday**?

_____ **hours per day**

_____ **minutes per day**

27. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekend day**?

_____ hours per day

_____ minutes per day

This is the end of the questionnaire, thank you for participating.

IPAQ-Scoring and Survey

The IPAQ- scoring is a PDF document that can be viewed and downloaded from the Karolinska Institute website. The IPAQ can be viewed at:

www.ipaq.ki.se. (Retrieved: 05/08/2009).

A downloaded version of the IPAQ as it appears in the PDF format will be printed and used for participant physical activity background.