VIRTUAL REALITY: ITS EFFECTS ON PHYSICAL ACTIVITY AND PAIN SENSITIVITY

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VIRTUAL REALITY: ITS EFFECTS ON PHYSICAL ACTIVITY INTENSITY AND PAIN SENSITIVITY

The ability of virtual reality (VR) active games to elicit moderate-to-vigorous physical activity (MVPA) has yet to be fully understood. Also, whether VR combined with physical activity could have a greater pain reducing effect compared to non-active VR distraction remains unknown. The purpose of this study was to evaluate the effects of commercial VR active games on physical activity intensity levels, enjoyment, and pain sensitivity in young health adults. Thirty-six (18 males, 18 females) participants completed four study sessions, with each devoted to playing one VR game for fifteen minutes. The games included Beat Saber, Holopoint, Hot Squat, and Relax Walk VR. Levels of physical activity reached during VR gameplay were measured with percentage of heart rate reserve (%HRR), ratings of perceived exertion (RPE), and accelerometry. Enjoyment was measured with a visual analog scale and the Physical Activity Enjoyment Scale following each gaming session. Pressure pain thresholds (PPT's) of the dominant forearm and ipsilateral thigh were conducted before and after VR gameplay. The primary outcome measures were analyzed with mixed model ANOVAs. The %HRR and RPE results showed that only Hot Squat consistently elicited moderate intensity activity. Accelerometry data showed that Hot Squat and Holopoint elicited higher whole body and lower body intensity levels than Beat Saber and Relax Walk VR. For enjoyment, Beat Saber and Holopoint were rated higher than Hot Squat and Relax Walk VR. Results for pressure pain thresholds (PPT's) showed 1) an overall acute hypoalgesic effect on the forearm and thigh following all VR games, and 2) an enhanced hypoalgesic effect

(combining MVPA and VR distraction) on the thigh following Hot Squat. Overall, results from this study suggest that active VR games can elicit varying degrees of physical activity intensity levels in young healthy adults, with Hot Squat eliciting moderate intensity activity. Thus, active VR games could be an alternative and enjoyable mode of obtaining physical activity. This study also showed that active VR games can elicit an acute hypoalgesic effect, with the effect potentially exacerbated with greater movement during gameplay.

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LIST OF ABBREVIATIONS

AG: Active Gaming

VR: Virtual Reality

MVPA: Moderate-to-vigorous physical activity

RPE: Ratings of Perceived Exertion

VAS: Visual Analog Scale

PACES: Physical Activity Enjoyment Scale

PPT: Pressure pain threshold

%HRR: Percentage of Heart Rate Reserve

METS: Metabolic equivalents

IPAQ: International Physical Activity Questionnaire

BMI: Body mass index

PAR-Q: Physical Activity Readiness Questionnaire

CHAPTER 1

INTRODUCTION

Background

Physical activity guidelines state that adults should participate in moderate aerobic activity 3 to 5 days per week for a minimum of 150 minutes (USDHHS, 2018). Approximately 57% of young adults between the ages of 18 and 24 meet the aerobic guidelines set forth by the U.S. Department of Health and Human Services; subsequently, about 50% of adults between ages 25 and 34 achieve the recommended guidelines regularly (CDC, 2013). A potential explanation for why there is such a high prevalence of sedentary activity among the young adult population is the regular participation in sitting behaviors including watching television and playing video games. It is suggested that nearly 50% of adults between the ages of 18 and 49 play video games on a regular basis (Weaver et al., 2009). In a longitudinal study evaluating sedentary behavior trends in the U.S. population, television watching remained relatively stable across a ten-year period, while computer use and sitting time increased an hour per day (L. Yang et al., 2019). Overall, data suggest that increased time in sedentary activities are associated with an increased risk in diabetes, cardiovascular disease, and all-cause mortality (Wilmot et al., 2012). As such, the prevalence of these sedentary behaviors demands an alternative approach to addressing physical inactivity.

Virtual Reality and Physical Activity

In the early to middle 2000s, there was a release of gaming consoles which allowed participants to use partial or whole-body movements to play video games instead of solely playing from sedentary positions. It was thought that this combination of video games and physical activity, called Active Gaming (AG), could assist in addressing the physical inactivity crisis in the young adult population (Bosch, Poloni, Thornton, & Lynskey, 2012; Scheer, Siebreant, Brown, Shaw, & Shaw, 2014; Wu, Wu, & Chu, 2015). To date, many studies have evaluated the effects of active gaming systems, like the Xbox One Kinect and Nintendo Wii systems, on physical activity intensity levels in various populations (Bosch et al., 2012; Scheer et al., 2014; Wu et al., 2015). Overall, studies show mixed results with most active games eliciting moderate intensity activity, some active games eliciting light activity, and very few eliciting vigorous intensity activity (K. E. Naugle & Wikstrom, 2014; Peng, Crouse, & Lin, 2013). Secondarily, another significant component within the AG literature is the enjoyment or positive emotions perceived while playing active video games. Generally, if positive emotions are present during exercise, this could promote future exercise participation (Williams, 2008). Specifically, it has been shown that young healthy adults find AG more enjoyable than traditional modes of aerobic activity (Graves et al., 2010; K. E. Naugle & Wikstrom, 2014). Therefore, AG may be an alternative and enjoyable form of obtaining regular physical activity.

In recent years, a novel form of gaming technology has emerged in the entertainment world, which promotes further engagement while playing video games. This newest format that enables AG, termed Virtual Reality (VR), allows participants to wear a head-mounted display system and use handheld controllers to interact with a virtually displayed environment through physical movements in all three planes of motion. Because VR is relatively new to the gaming industry, little is known about its effects on physical activity intensity levels and whether VR shows the ability for gamers to achieve moderate-to-vigorous intensity activity. The first active VR study demonstrated that three different active VR games elicit activity in the moderate intensity range; however, these results are limited as the authors did not statistically analyze the data (Yoo, Ackad, Heywood, & Kay, 2017). The most recent active VR study showed that participants reached moderate intensity in two games and vigorous intensity in another game during 10 minutes of gameplay (Gomez, Bagley, Bolter, Kern, & Lee, 2018; Yoo et al., 2017). Neither study evaluated participant enjoyment during gameplay. While these initial studies show promising results, more research is necessary to assess whether VR games can be an enjoyable alternative or additive approach to meeting physical activity guidelines.

Virtual Reality and Pain Perception

While research on commercial, active VR games as an exercise tool is scarce, research on VR as a method of pain reduction has significantly grown in the past 2 decades. This research suggests that passively engaging in VR (little-to-no physical activity) has a positive effect on acute pain sensitivity in healthy adult populations as well as clinical populations (Glennon et al., 2018; Jin, Choo, Gromala, Shaw, & Squire, 2016; Law et al., 2011; Magora, Cohen, Schochina, & Dayan, 2006). It is suggested that the VR mechanism that reduces pain perception in adults primarily relies on distraction, where participants' attention is directed towards the VR environment instead of the pain stimulus (Hayashi, Aono, Shiro, & Ushida, 2019). For example, in an earlier study examining the effects of VR on ischemic pain, participants reported lower pain levels and spent less time thinking about the induced pain while engaging in a VR environment (i.e. interactions within a kitchen environment) compared to not undergoing a VR stimulus

(H. Hoffman, Garcia-Palacios, Kapa, Beecher, & Sharar, 2003). Interestingly, a recent study demonstrated that VR combined with exercise imagery (i.e., running imagery) had a greater hypoalgesic effect on pressure pain thresholds (PPT) compared to pure VR distraction (Hayashi et al., 2019). Exercise imagery increases brain activity in the motor and premotor cortex similar to if actual movements were occurring (Lotze & Halsband, 2006; Miller et al., 2010), and thus may introduce another mechanism through which pain could be decreased. Indeed, extensive research shows that a single bout of exercise of sufficient duration and intensity exerts a temporary hypoalgesic effect in healthy adults, termed exercise-induced hypoalgesia (K. M. Naugle, Fillingim, & Riley, 2012). Furthermore, physical activity through AG has been shown to reduce pain perception in two different models of experimental pain (Carey, Naugle, Aqeel, O'hlman, & Naugle, 2017; K. E. Naugle, Parr, Chang, & Naugle, 2017). As such, separately both physical activity and VR have the ability to attenuate pain in healthy adults. Whether hypoalgesia could be enhanced when the distraction effects of VR are combined with exercise-induced hypoalgesic effects compared to either method (VR-distraction only or exercise) alone is unknown.

Significance

Overall, the lack of physical activity in our society demands non-traditional means to meeting physical activity recommendations to obtain and maintain health benefits. Virtual reality (VR), which translates physical motions to a game setting through a head-mounted display system, is a new form of gaming technology which allows participants to interact within a realistic environment by projecting physical movements into the virtual world. What is not known is whether commercial virtual reality technologies are able to induce moderate levels of physical activity and high levels of enjoyment. As gaming technology improves, it is relevant to assess whether new gaming systems are able to address physical inactivity with alternative as well as enjoyable modes to meet physical activity recommendations. Also, what is not known is whether VR combined with physical activity could have a greater pain reducing effect compared to non-active VR distraction. Therefore, the overall goal of this research project was to evaluate the effect of VR gaming technology on physical activity intensity levels, enjoyment, and pain perception in healthy younger adults. This study addressed the following specific aims:

Specific Aim 1: Determine the ability of commercial VR games to induce moderate-to-vigorous physical activity intensity levels in young healthy adults.

> **Hypothesis A:** Active VR games would yield higher physical activity intensity levels than non-active VR games.
>
> **Hypothesis B:** Active VR games would allow participants to reach moderate intensity activity as defined by heart rate, accelerometry, and ratings of perceived exertion (RPE).

Specific Aim 2: Determine which active VR games elicited higher enjoyment levels in young, healthy adults.

> **Hypothesis:** VR games requiring more body movement would elicit higher enjoyment levels than games requiring less body movement.

Specific Aim 3: Assess whether playing VR games would have an acute hypoalgesic effect on experimentally induced pain in young, healthy adults.

Hypothesis A: Playing VR games would have a significant acute hypoalgesic effect following each gaming session.

Hypothesis B: Playing active VR games which required more physical activity would have a greater hypoalgesic effect than the non-active VR games (NVR).

Delimitations

The study's delimitations included:

1. The study population and sample included young, healthy adults between 18 and 30 years of age.
2. Only four VR games were chosen to evaluate within this study (Relax Walk VR, Beat Saber, Holopoint, and Hot Squat), even though a multitude of VR games currently exist.
3. The HTC Vive was the VR system used within this study, though other alternatives are available.
4. The duration of gameplay per game was limited to fifteen minutes to reach steady state activity without becoming overly fatigued.

Assumptions

1. Participants would understand the ratings of perceived exertion (RPE) scale as described by the researcher and participants will give a truthful response in assessing their gameplay exertion.
2. In the assessment of pain sensitivity, participants would understand the purpose of the pressure pain threshold test as described by the researcher

and will honestly signal to the experimenter when pressure first begins to feel painful.

3. Participants would provide truthful enjoyment ratings for each game.

4. When assessing session exclusion criteria, participants would respond accurately to the questions regarding the session exclusion criteria.

CHAPTER 2

LITERATURE REVIEW

Introduction

The purpose of this review was to synthesize relevant literature concerning AG technologies on physical activity intensity levels, emotional responses, and pain sensitivity in healthy young adult populations. Active gaming broadly refers to the combination of physical activity and video gaming, where physical movement in the form of partial or whole-body movements are used to participate in the game. First, a section on how active gaming technologies influence physical intensity levels is presented. This section starts with a brief history of active gaming followed by a description of common methods of measuring physical activity intensity levels in adult populations. Next, a concise discussion of the research on active gaming technologies and their effects on these intensity measures is provided, starting with older gaming systems and progressing through newer technologies, ultimately culminating with virtual reality.

Secondly, a review of the research evaluating emotional responses to active gaming is provided, starting with a brief overview of common methods used to evaluate such responses. Similar to the first section, the review will start with older gaming technologies and end with virtual reality technology. Third, a section reviewing the literature focused on the effect of active gaming and VR on experimentally induced pain in healthy, young adults is provided. Lastly, implications for future research in the realm of virtual reality in these three areas are discussed.

Physical Activity through Active Gaming

Commercially available active gaming systems were introduced in the mid-2000s as a means for participants to become more physically active. These gaming systems have evolved over time and have undergone significant changes in technological advancements. A main component of gaming consoles included using handheld controllers in which motion sensors track controller movement. Over time, another improved technological element in gaming systems included motion tracking which requires no controller. The latest iteration of gaming systems utilizes head-mounted displays and controllers to immerse players in a virtual environment to play games. With such progression to new gaming technologies, the following sections will review the evidence on how these various gaming systems impact physical activity levels in healthy adult populations. However, before a comprehensive evaluation of such gaming systems can be given, a brief description of the common methods of measuring physical activity intensity during active gameplay is provided.

Measures of Physical Activity Intensity

Most of the measures of physical activity during active gaming include those based on heart rate monitoring and motion sensors (e.g., accelerometers), those based on energy expenditure and oxygen uptake, and subjective measures such as ratings of perceived exertion. All the measurement techniques have inherent advantages and disadvantages, with combined approaches often providing optimal value and a more comprehensive evaluation of physical activity. The following review of intensity measures is not designed to provide a comprehensive evaluation of these measures, but rather designed to enhance interpretation of the literature in this review that focuses on physical activity effects of active gaming.

Heart Rate. Tracking heart rate changes is a common, non-invasive, and relatively inexpensive method of evaluating intensity level during physical activity. The two primary methods of using heart rate measures to describe physical activity intensity levels are percentages based on age-predicted maximal heart rate and heart rate reserve (HRR). Calculating the percentage of maximal heart rate achieved during physical activity involves the following formula: [heart rate during activity/(220 – Age)]*100. The Karvonen formula can be used to calculate the percentage of HRR that participants achieve while performing physical activity. This formula is related to the percent of age-predicted maximal heart rate but allows for differences in resting HR (RHR) (Karvonen, 2007). First, heart rate reserve is calculated using the following method: age predicted maximal heart rate – resting heart rate. Percentage of HRR during activity can then be determined by using the following formula: [(average HR during activity – resting heart rate)/HRR] x 100. It is suggested that adults between the ages 20 and 39 years should participate in aerobic activities with heart rate values between 46% and 64% of age-predicted maximal heart rate or between 40 - 60% of their heart rate reserve to achieve moderate intensity activity (ACSM, 2018). These methods of measuring heart rate during physical activity are considered valid methods of measuring physical activity intensity (Strath et al., 2000; Swain, 1997).

Accelerometry. While measuring heart rate is able to give an overall assessment of physical activity intensity, accelerometry is able to provide valuable information regarding intensity of actual body movement each second. Accelerometers are frequently used for the objective measurement of physical activities in various populations, ranging from adolescents to adults (S. Duncan et al., 2018; Jarrett, Fitzgerald, & Routen, 2015; Sanders et al., 2019). Accelerometers are usually worn on the waist, as a measure of whole-body activity, but can also be worn on the wrist or ankle. Generally, accelerometers are built with sensors that detect acceleration in all planes of motion and are translated into signals that are later converted into arbitrary units called "counts." After conversion, these counts are categorized into various intensity levels (i.e., ranging from sedentary to vigorous intensity) using established cut-points (S. Duncan et al., 2018; Ward, Evenson, Vaughn, Rodgers, & Troiano, 2005). One advantage of accelerometry over other intensity measures is that the devices enable measurement of physical activity and sedentary behaviors. Additionally, when accelerometers are worn on multiple body parts simultaneously, information can be obtained on whether movement during active gaming is primarily in the upper extremities vs. whole body.

Energy Expenditure. Energy expenditure (EE) via indirect calorimetry is a common method to objectively measure physical activity intensity levels. Energy expenditure is quantified on the basis of oxygen consumption during a given activity. Oxygen consumption is measured using a metabolic cart system. An individual wears a mask and breathed air is moved through an airline where it is then analyzed by the metabolic cart. Portable and wearable metabolic analyzers have also been developed to give participants the ability to roam more freely without being tethered to a metabolic cart station. Common metrics calculated from oxygen consumption values are kilocalories (kCal) per minute or metabolic equivalents (METs). One MET (metabolic equivalent) is defined as a rate of energy expenditure equivalent to an oxygen uptake of

3.5 mL x kg-1 x min-1 at rest (Committee, 2008). To calculate the METS reached for an activity, the following formulaic method is used: (VO2 during activity)/(VO2rest). Light intensity physical activity is defined as 1.1 to 2.9 METs, while moderate intensity is defined as 3 to < 6 METS, and vigorous intensity is ≥ 6 METs (ACSM, 2018; Ainsworth et al., 1992).

Ratings of Perceived Exertion. Ratings of perceived exertion (RPE) is a subjective method used to identify one's perception of physical exertion during an activity. The most common form of RPE is the Borg 6-20 scale. This scale displays verbal descriptors associated with physical exertion alongside numerical values from six to twenty, with the lowest value mirroring "no exertion at all" and the highest value being "maximal exertion" (Borg, 1982). RPE values 9 to 11 are associated with light activity, 12 to 13 with moderate activity, and 14 to 17 with vigorous activity (ACSM, 2018; Garber et al., 2011).

Physical Activity through Active Gaming: Systems with Controllers

With the onset of interactive games, the primary means to play active games was to use some form of controller, most commonly being handheld controllers. These gaming systems often utilized handheld controllers where a motion sensor would track the movement of the controllers and translate the movement to a monitor screen. Another mode of gaming technology utilized a floor pad with sensors, which tracked lower body movement and similarly translated the motions to the monitor. The following section will provide a comprehensive review on AG literature using these methods of gameplay, with the most common system being the Nintendo Wii.

Early Gaming Systems

Early AG researchers used older gaming systems to study how such games, which were designed primarily for player enjoyment, could affect physiological variables in healthy adult populations. Siegel et al. evaluated active video and arcade games on energy expenditure in college students using three dated gaming systems and games. The three games were 3-Kick, Jackie Chan Studio Fitness Power Boxing, and Disney's Cars Piston Cup Race. The 3-Kick game incorporated three separate posts with sensors in which participants either punched or kicked when a light flashed on the post. The Power Boxing game allowed participants to use boxing gloves with sensors and perform punching motions similar to a boxing match. The Cup Race game utilized a stationary cycle in which participants cycled to race a virtual on-screen car against opponents. While collecting physiological data using a portable metabolic cart, participants were allowed to switch between games during a 30-minute period of gameplay performed at self-selected intensity. While there were no differences between games in terms of heart rate and energy expenditure, the results revealed that collectively participants reached significantly higher heart rates during game play (162.8 + 10.8 bpm) when compared to resting values (82.3 + 11.4) and that energy expenditure during game play (7.5 + 1.6 kCal/min) was consistent with ACSM recommendations for exercise intensity (Siegel, Haddock, Dubois, & Wilkin, 2009).

In a more commonly available gaming system, Sell, et al. evaluated the effects of a Playstation 2 dance game (Dance Dance Revolution) on energy expenditure in male college students with different gaming experiences. This game used a floor pad with four directional arrows in which participants matched to on-screen arrows in time with a corresponding song. Nineteen participants played at a self-selected pace continuously for 30 minutes while energy expenditure, heart rate, and ratings of perceived exertion were collected. Results from this study showed that experienced players (who voluntarily choose to play at higher difficulty levels) expended more energy (10.5 + 5 kcal x min-1) and achieved higher average heart rates (161.2 + 13.8 bpm) than inexperienced players (who played at lower difficulty levels) during gameplay (4.8 + 1.0 kcal x min-1, 95.5 + 10.5 bpm). Similarly, experienced players perceived their gameplay more difficult (13.4 + 1.5) with higher RPE scores than the inexperienced group (10.7 + 1.7), which was consistent with the energy expenditure findings. These findings also showed that experienced players reached intensity levels consistent with moderate intensity activity, while inexperienced players primarily stayed within light intensity (Sell, Lillie, & Taylor, 2008).

Past research has also evaluated the Dance Dance Revolution game (DDR) as a mode of physical activity compared to traditional exercise. Kraft et al. compared playing DDR to a video game interactive bicycle ergometer (CatEye GB 300) and riding a traditional Monarch cycle ergometer while watching television. Thirty-seven college-aged (20 men, 17 women) participants played each game at self-selected intensities continuously for 30 minutes on three separate days. Individualized target heart rates (>40% HRR) using the Karvonen method were used as a metric of exercise intensity and time spent above target heart rates were recorded. RPE was collected using a modified Borg 10-point scale every 5 minutes during gameplay. Results from this study showed that average HRR% values during DDR gameplay reached approximately 37% HRR with only one-third of total gameplay time spent above 40% HRR. While playing the interactive bicycle game, participants had average HRR values near 57% with nearly 23 minutes spent above 40% HRR, consistent with moderate intensity activity. The results demonstrated similar findings for RPE, with DDR (2.5 + 1.5) having lower RPE values than values given during interactive bicycling (4.6 + 1.7). In comparing the games to the cycle ergometer, results showed that time spent above target heart rate during DDR was similar to cycle ergometry, with the interactive bicycle ergometer eliciting the highest time above heart rate among all conditions. While experience was not controlled for in this study, the authors' noted that AG skill level may be a contributing factor in heart rate changes when comparing DDR with traditional forms of exercise (Kraft, Russell, Bowman, Selsor III, & Foster, 2011).

Although these gaming systems are older and currently outdated, initial AG studies suggest that healthy participants are able to reach light to moderate physical activity intensity levels while playing at self-selected intensities. Early AG literature also suggests that prior gaming experience may influence energy expenditure levels due to the more experienced players being able to play the games at higher difficulty levels.

The Nintendo Wii

As reviewed in the prior section, relatively few studies have examined physical activity levels during game play in older gaming systems. However, extensive research has evaluated one of the most popular gaming systems, the Nintendo Wii. The Nintendo Wii became commercially available in 2006 and incorporates a controller, which tracks physical motion and relays it to gameplay movement.

Early Nintendo Wii studies have evaluated metabolic and heart rate responses in both experienced and inexperienced participants. Bosch and colleagues assessed exercise intensity in twenty young adults (23-27 years) while playing the Nintendo Wii continuously for thirty minutes. Participants played Wii Boxing, which incorporates handheld controllers where participants mimic punching motions. By measuring percentages of maximal heart rate, the authors found that eight participants averaged moderate intensity (64-76% HRmax) and ten participants averaged vigorous intensity (77-93% HRmax), regardless of any experience with the Nintendo Wii system or boxing game (Bosch et al., 2012). However, the results also revealed a lower mean heart rate response for experienced compared to inexperienced participants. In a similar study, O'Donovan et al. evaluated energy expenditure during Wii Fit games and Wii Sport games, while also considering the impact of gaming experience on energy expenditure during game play. All participants played Wii Sport Boxing. Participants in the Wii Fit group also played Free Jogging, while those in the Wii Sports group also played Tennis and Baseball. Each group played each game for fifteen minutes with five-minute breaks between games. Participants wore a portable metabolic analyzer system that collected oxygen consumption, energy expenditure, and heart rate. Based on %HRmax and MET values, only Jogging (71 + 13 % HRmax) reached moderate intensity while all other activities remained within light-activity intensity. The results showed a gaming experience effect for Tennis, in which the HR and %HRmax achieved by experienced players were significantly lower than those without prior gaming experience. The authors speculated that the lower values from the experienced players during Tennis may be attributed to more efficient controller skill, as the Tennis game requires more controller skill than the other Wii games (O'Donovan & Hussey, 2012). Taken together, the Bosch and O'Donovan studies suggest that those with less gaming experience may initially benefit more from playing active games, but prolonged physiological benefits may require more complex, interactive games if active games were regularly played. However, future research is needed to test this hypothesis. Also, between these two studies, Nintendo Wii Boxing was a common game evaluated in young adults. The results by Bosch et al. showed that a majority of participants averaged moderate intensity consistently during Wii Boxing, while results by O'Donovan, et al. showed that participants averaged light activity. These contrasting results could be due to the longer duration of game play in the Bosch study (30 minutes vs. 15 minutes) and because at the end of each boxing match in the Bosch study the experimenter encouraged the participants to keep moving in order to promote continuous play throughout the 30 minutes.

Other Nintendo Wii studies have compared different modes of active games in young adults. Indeed, Rodriguez et al. evaluated the acute cardiovascular effects of playing aerobic- (Obstacle course, Hula hoop, Free run) and balance-based (Soccer heading, Table tilt, Penguin slide) Nintendo Wii games in healthy younger adult males. Participants completed an incremental treadmill test to obtain maximal oxygen consumption, heart rate, and METS in one session. In a second separate session, participants randomly played all the Wii games twice for eight-minute bouts with five-minute rest periods. During the gaming session, participants wore a wearable metabolic cart unit that collected physiological variables and were encouraged to work up to their maximal game performance. Results showed that oxygen consumption, percentage of maximal heart rate, and METS for the aerobic-based Wii games were significantly higher than for the balance-based games. For the aerobic games, moderate intensity was reached during Hula hoop (61.66 + 13.61 %HRmax) and Free run (64.35 + 13.70 %HRmax), while playing Obstacle course (48.44 + 6.90 %HRmax) only elicited light intensity. No balance game reached levels consistent with moderate intensity activity as defined by %HRmax, oxygen consumption, or METS (Rodrigues, De Souza Felipe, Silva, & al., 2015).

Mullins et al. was also interested in evaluating the physiological effects of different modes of Nintendo Wii games in older and younger adults. Four different categories of games were played including: yoga (Warrior, Tree, Standing Knee), balance (Ski Slalom, Table Tilt, Balance Bubble), aerobics (Advanced Step, Super Hula Hoop, Rhythm Boxing), and strength (Single-Leg Extension, Plank, Rowing Squat). Participants randomly played three five-minute segments for each game group while wearing a portable metabolic cart and heart rate monitor. During each 15-minute bout, participants gave an RPE score during the midpoint of each five-minute segment. Results from this study showed that the aerobic games elicited higher %HRR, METS, energy expenditure, and RPE than the balance and yoga games. The %HRR values reached while playing the aerobic games were consistent with moderate intensity (40.46 + 13.41%), with METS approaching the moderate range (2.41 + 0.58). RPE mirrored the intensity levels with exertion approximating "light" to "somewhat hard" (11.37 + 1.79). The authors noted that though active gaming intensity leaned towards light to low-moderate, the aerobic active games could improve cardiovascular health in sedentary and unfit individuals while also aiding in achieving physical activity recommendations (Mullins, Tessmer, McCarroll, & Peppel, 2012).

Previous research has also compared playing active video games to other traditional forms of aerobic activity. Perron et al. evaluated playing "Island Cardio Blast" on Nintendo Wii to treadmill walking at self-selected paces in seventeen females (22.6 + 3.2 years) and thirteen males (26.2 + 9.1 years). Heart rate via heart rate monitors, accelerometers worn on the right hip, and RPE (6-20) were used to measure exercise intensity. On separate sessions, participants played Island Cardio Blast for 30 minutes and treadmill walking for 40 minutes. Based on accelerometer data, participants spent more time in moderate activity during treadmill walking (66.5% of duration) than playing the Wii game (27.0% of duration). However, average heart rate was higher during active gameplay than treadmill walking, and perceived exertion was higher while playing Wii (13.1 + 1.9) than treadmill walking (11.6 + 2.0). The heart rate values achieved during Wii gameplay translated to 76% HRmax, which is within the ACSM guidelines for moderate intensity. The accelerometer data conflicted with HR and RPE findings by showing more time spent in moderate or higher physical activity intensity during treadmill walking than playing the Wii. The authors suggested this could have been attributed to the hip accelerometers failing to register movement during Wii gameplay that used significant upper-body movement (Perron, Graham, & Hall, 2012).

Another study also evaluated the physiological costs of playing different Nintendo Wii games compared to traditional forms of aerobic activity and seated games. Specifically, Graves et al. assessed oxygen consumption, METS, and heart rate in adolescents, young adults, and older adults during the following seven activities: handheld interactive gaming, Wii yoga, Wii muscle conditioning, Wii balance, Wii aerobics, treadmill walking, and treadmill jogging. Participants completed these activities at self-selected paces for ten minutes with a five-minute resting period between each activity: Results showed that all age groups had higher METS and heart rate while playing the Nintendo Wii games than when playing the seated handheld game. However, physiological variables during Wii gameplay were lower when compared to treadmill walking and jogging. This result may be attributed to the intermittent nature of the Nintendo Wii games that are played at a self-selected intensity. Certain games may include intermittent pauses or breaks during gameplay and between games bouts, which may account for lower physiological responses during active gameplay compared to treadmill walking. While METS were lower when compared to traditional aerobic activities (8.0 + 1.2), young adults reached moderate intensity activity while playing the aerobics Wii games (3.6 + 0.8). Wii yoga (1.9 + 0.4), Wii muscle strength (2.4 + 0.4), and Wii balance games (1.9 + 0.5) stayed within light intensity (Graves et al., 2010). In a similar study, Douris et al. evaluated heart rate, respiratory rate, and RPE responses to playing Nintendo Wii games and traditional aerobic activity in sedentary, college-aged students. In two separate sessions, participants walked on a treadmill for thirty minutes at a 3.5 mph pace and completed a thirty-minute gameplay of the Nintendo Wii "Free Run" game. Douris and colleagues found that heart rate (142.4 + 20.5 vs. 123.2 + 13.7) and perceived exertion (12.7 + 3.0 vs. 10.1 + 3.3) were higher while play Free Run compared to moderate-intensity walking (Douris, McDonald, Vespi, Kelley, & Herman, 2012).

Because AG outcomes may vary across young adult populations with different physical activity regimens, Naugle et al. compared the effects of four Nintendo Wii games (Boxing, Tennis, Step, and Cycle) against two modes of traditional aerobic exercise (treadmill walking and stationary bike) in a high-intensity exercise group (those who typically exercise at a high intensity) and a low-intensity exercise group (those who typically exercise at a low intensity). The six activities were spread over three experimental sessions with two activities performed for 20 minutes per session. Participants performed the Wii games at self-selected intensities, while the traditional modes were performed between 11 and 13 RPE values (moderate pace). Heart rate and RPE were collected every five minutes. The low-intensity exercise group reached an average intensity of greater than 40% HRR while playing Wii Boxing, but %HRR was significantly lower during the games compared to treadmill-walking and stationary cycling for both groups. Interestingly, the low-intensity exerciser group achieved a greater %HRR playing Wii Boxing compared to the high-intensity exerciser group playing any Wii game. For the high-intensity exercise group, only treadmill-walking and stationary cycling elicited %HRR values consistent with moderate intensity while the active games elicited light intensity. The RPE results generally mirrored the HR findings, with the highest RPE values given during treadmill-walking and cycling. These results suggest that the exercise background of participants and game selection are important factors that can influence the intensity level achieved during active gameplay (K. E. Naugle, Naugle, & Wikstrom, 2014).

In summary, the AG literature evaluating the Nintendo Wii system suggests that Wii games can elicit moderate intensity activity and mirror intensity levels achieved during traditional exercise. However, such mirroring is dependent on the type of game being played, gaming experience, and exercise background of participant. For example, games designed with an aerobic component compared to balance, yoga, or strength games elicit higher intensity levels. In the use of Wii games as a mode to increase cardiovascular fitness, the games appear to be more suited for less fit individuals and those who prefer to exercise at lower intensities.

Active Gaming: No Controllers

Gaming technologies have improved drastically over time. While much research has evaluated controller-based gaming systems (i.e., the Nintendo Wii), new technologies have become commercially available that allow participants to play games with no controller. Such technologies, specifically the Xbox game console with the Kinect sensor attachment, track body movements and translate those movements to gameplay activity.

Early research on the Xbox Kinect evaluated differences in sports-based Kinect games in healthy adults. Wu et al. assessed how playing various Xbox "Kinect Sports" games affected energy expenditure and intensity levels in healthy young adults. Participants completed an aerobic capacity assessment, a games familiarization session, and two sessions devoted to three active games per session. During the active video game sessions, oxygen consumption (VO2), heart rate, and energy expenditure were measured. Active games from "Kinect Sports" during the first session included beach volleyball, soccer, and boxing, while the second session included ping-pong, bowling, and track and field. Participants played each game for ten minutes with settings at amateur level with a five-minute rest period between games. The primary finding was that five out of the six games were able to induce moderate-to-vigorous activity. On average, MET values for boxing and soccer (6.84 + 1.87, 6.23 + 1.91 respectively) fell within vigorous intensity, while volleyball, track and field, and ping-pong induced moderate intensity activity (5.73 + 1.80, 4.98 + 1.48, 4.05 + 1.59 respectively), and bowling only reached light intensity (2.61 + 0.77). Intensity measured with average oxygen consumption and heart rate mirrored intensity levels measured via MET values during active gameplay. Results from this study suggest that young, healthy adults can reach moderate-to-vigorous intensity while playing Kinect sport games consistently. This also suggests that those with varying game interests can choose one of these games and reach these intensity levels (Wu et al., 2015).

While the prior study compared different active Kinect games, Barry et al. compared active video games to sedentary (seated) video games in young, healthy adult males. Nineteen males participated in two sessions separated by at least 48 hours, with the first session being devoted to familiarizations, resting measures, and an incremental exercise treadmill test. The second session was devoted to both sedentary and active video games. Active games included the Kinect "Adventures" games "Reflex Ridge" and "River Rush," and Kinect "Sports: Boxing." Sedentary games included "Call of Duty" and "FIFA 14." All games were randomized with each game being played for fifteen minutes. During gameplay, heart rate and oxygen consumption were continuously measured, and RPE was collected every three minutes. Results showed that all outcome measures were significantly higher while playing the active video games than playing the sedentary games. Based on percentage of maximal heart rate, all active games fell between 64 – 67% HRmax, which is considered moderate intensity activity. However, MET values reached while playing the active games were in line with vigorous intensity (>6 METS), with "Reflex Ridge" eliciting the highest intensity (8 + 2). Average RPE values given during the active games ranged from 11 – 13 on the Borg 6-20 scale, which is associated with "light" to "somewhat hard." Overall, this study suggests that playing the aforementioned active Kinect video games elicit higher intensity levels when compared to playing seated video games and that moderate-to-vigorous intensity can be reached, which would be in congruity with physical activity recommendations (Barry et al., 2016).

Yang et al. also evaluated the impact of playing the Xbox Kinect system on physical activity intensity levels in sedentary college students. While wearing a metabolic cart unit, heart rate monitor, and a hip and wrist accelerometer, participants (20.75 + 1.8 years) played two fifteen-minute bouts of the Xbox Kinect game “Your Shape Fitness Evolved 2012” with a five-minute break between each bout. The activity chosen from the game was “Break a Sweat,” which focuses on short bursts of high intensity activity. Data from hip-worn accelerometers showed that 29.95 + 0.22 minutes of play time (99%) was spent in moderate-to-vigorous activity with corresponding average METS being 5.91 + 0.46. Wrist-worn accelerometer data showed that 100% of upper extremity activity during gaming was spent in moderate-to-vigorous activity, with METS expended being 7.04 + 0.48. Indirect calorimetry showed similar findings with time spent in moderate-to-vigorous activity 27.90 + 1.37 minutes (93%), with MET values averaging within moderate intensity (5.48 + 0.88). Overall, this study suggests that this exercise-based active game can elicit consistent levels of moderate-to-vigorous intensity activity (C. Yang et al., 2014).

In summary, most Xbox Kinect games studied are able to elicit moderate intensity activity and significantly higher intensity levels when compared to stationary or seated Xbox games. Also, sedentary young adults can benefit physiologically from playing Kinect games and reach moderate to vigorous intensity activity. Lastly, as with the

Nintendo Wii, game genre may influence different intensity levels as game modes may demand different body movement and movement intensities.

Active Gaming: Comparison across Game Systems

The prior sections have focused on studies evaluating the effects of single gaming systems on physical activity intensity levels. However, several studies have evaluated physical activity during games from different gaming systems within the same study (e.g., Wii games vs. Kinect games). The following section will review the research focusing on such gaming system comparisons.

Parent et al. compared energy expenditure in young male adult gamers between two popular gaming systems, the Xbox Kinect for body movement tracking and PlayStation Move for controller movement tracking. Ten male participants played games compatible for both Kinect and PlayStation systems (Just Dance 3 and Adidas MiCoach) with the exception of one game type (No More Heroes for PlayStation, and Star Wars for Kinect). The sessions using PlayStation incorporated a sitting and standing session to compare energy expenditures, while Kinect games could not track movements in a seated position. Participants randomly played each game for each console between 12 and 15 minutes while wearing a portable breath-by-breath analyzer and heart rate monitor to constantly measure oxygen consumption, heart rate, and energy expenditure. The main finding from this study was that moderate-to-vigorous intensity was achieved in Just Dance 3, Start Wars for Kinect, and MiCoach games for both consoles. Intensities (METS and %VO2max) were significantly higher while playing Kinect than playing PlayStation even though the same games were played on both systems. The authors suggested that more movement was associated with the Kinect than the movement required in the PlayStation version of the same game due to the PlayStation version requiring more focus on button controls than physical movement during gameplay. Results also showed that higher intensities were reached during gameplay in standing positions when compared to sitting when playing Just Dance 3, with standing gameplay reaching moderate intensity and sitting-gameplay inducing little to no physical activity levels. In support of this result, prior research suggests that active games which regularly include lower body movements have a greater ability to elicit higher energy expenditures than active games requiring primarily upper body movements (Jordan, Donne, & Fletcher, 2011). Notably, the Parent et al. study also demonstrated moderate intensity was still reached during sitting activity, which suggests, if the self-selected intensity was high enough, individuals with lower body physical limitations, may benefit from participating in these active games (Parent & Comtois, 2019).

Duncan et al. assessed energy expenditure in young adults playing the Nintendo Wii and Gamercize Power Stepper. Thirty young adults (21.3 + 2.4 years) completed one familiarization and one experimental session. During familiarization, participants were introduced to the games for the subsequent experimental session, and completed treadmill walking at a self-selected intensity for five minutes. For the experimental session, participants wore a monitor that fits on the upper arm to track physiological measures during activity. Participants randomly played each of the following games for 10 minutes with a 10-minute rest period between each activity: sedentary gaming (Fifa Football or Sega Tennis), Nintendo Wii Just Dance, and Sega Tennis with the Gamercize Power Stepper. Results from the study showed that all movement activities elicited higher energy expenditures than sedentary gaming and that the Gamercize Stepper elicited higher energy expenditures than Nintendo Wii, but similar to treadmill walking. Overall, both active gaming conditions reached moderate intensity activity, which mirrors brisk walking. The authors suggest that the continual lower body movement of the Gamercize Stepper could have contributed to higher physiological values observed in the young adults when compared to Nintendo Wii Just Dance, in which intermittent rest periods are present (M. Duncan & Dick, 2012).

Instead of comparing active games to sedentary games, Scheer et al. compared three gaming systems (Nintendo Wii, Sony Move, and Microsoft Kinect) by measuring physiological variables during gameplay against the computer and during gameplay against another human opponent. Nineteen participants completed a maximal aerobic fitness test in the first session with the games being played in the subsequent session. The games played during the experimental session included primarily upper body motions, such as punching and dodging (Nintendo Wii Sports Boxing, Microsoft Kinect Boxing, and Playstation Move Gladiatorial Combat). Participants randomly played each game with a two-minute rest period between each bout while wearing a heart rate monitor and metabolic cart. All gaming conditions elicited similar increases in heart rate, minute ventilation, oxygen consumption, and energy expenditure above resting values. While there were no differences between playing against the game computer or human opponent, the physiological measures during gameplay did not meet established guidelines for health promoting exercise. Contrary to what Parent, et al. found, the results showed no differences in the intensity of physical activity obtained by playing motion-tracking games (Kinect, Move) compared to controller-based games (Nintendo Wii). The authors suggested that the general upper-body motion required to play these games may not by itself induce physiological changes consistent with higher physical activity intensities levels. This notion is supported by prior research suggesting that maximizing lower body movement could increase overall energy expenditure during game play (Jordan et al., 2011; Scheer et al., 2014).

To address the concerns that some active games may not consistently allow players to reach moderate-to-vigorous intensity activity, Naugle, et al. evaluated whether implementing standardized instructions to maximize movement during active gameplay would increase energy expenditure in healthy adults. Twenty-one younger adults completed six sessions (one familiarization, one baseline measures, and four experimental). Games included Nintendo Wii Boxing and Kinect Fighter Within (punching and kicking game), and Kinect Tennis and Nintendo Wii Tennis. In each experimental session, participants played two fifteen-minute bouts of an active game, with the first bout played at a self-selected intensity, and the second bout played with structured instructions given prior to gameplay. These instructions were designed to keep participants moving during game down time as well as using full range of motion on movements such as punches and kicks. During each bout, physiological measures including oxygen consumption, heart rate, and energy expenditure were collected via a wearable metabolic cart unit. Accelerometers were worn on the right hip and dominant wrist; and RPE values were collected every five minutes during gameplay. Results showed that during self-selected gameplay, participants reached moderate intensity during Kinect Fighter Within but generally maintained light physical activity during the other games. However, during the structured gameplay, participants consistently expended energy mirroring moderate intensity activity during all games. Accelerometers worn on the hip supported these findings as time spent in whole-body moderate-to-vigorous activity (MVPA) during self-selected gameplay ranged between 1 and 6% of game time while whole-body MVPA during structured gameplay increased to nearly 50% of game time. Naugle and colleagues also examined which accelerometer-based variables (i.e., percentage of time spent in whole body and arm light PA, MVPA, and sedentary time) predicted energy expenditure during game play. Percentage of time spent in whole-body moderate-to-vigorous activity during game play was the only variable that predicted METS during active gameplay. These findings are in line with prior evidence suggesting a positive relationship between lower-body movement and energy expenditure during active gameplay (L. E. Graves, Ridgers, & Stratton, 2008; Jordan et al., 2011). Overall, these results suggest that maximizing whole-body movement with both lower and upper body movements is important to reaching activity levels consistent with moderate and vigorous intensity (Naugle et al., 2019).

In sum, studies evaluating different gaming systems (controllers versus no controllers) have shown to varying degrees the ability of active games to elicit moderate to vigorous intensity activity when played at self-selected intensities, with some games failing to reach moderate intensity and others succeeding. Overall, active games that incorporate whole-body movement during gameplay promote higher intensity activity, regardless of the gaming system being played. As seen with prior studies evaluating singular systems, game genre also likely influences physical activity intensity levels reached during gameplay.

Active Gaming: Virtual Reality

In the latest iteration of active games, virtual reality (VR) incorporates an immersive experience in which participants wear a head-mounted display headset and hold controllers. This system (ex. HTC Vive or Oculus Rift) allows the user to become immersed in a 360-degree virtual environment and interact with his/her surroundings. Because this type of gaming technology is relatively new, the effects of VR gaming on physical activity intensity has yet to be fully understood, and therefore more research needs to be conducted.

In one of the first studies assessing physical activity during commercial VR games, Yoo et al. measured heart rate and RPE during VR gameplay in ten participants (18-37 years). The study compared three active VR games (Fruit Ninja, Hot Squat, and Holopoint) and one game acting as a control (Portal Stories: a puzzle-solving game with little physical movement). Fruit Ninja is primarily an upper-body game where the player slices various fruits in half. Hot Squat is primarily a lower-body game where the player squats up and down to avoid incoming objects. Holopoint uses controllers to simulate a bow and arrow to shoot distant and incoming targets. During each session, participants underwent the built-in VR tutorial prior to any gameplay to re-familiarize with equipment. Each game was played between five and ten minutes while wearing a heart rate monitor. During the rest period between each game, participants were asked to give an RPE rating that represented their maximal exertion during gameplay. Importantly, this pilot study reported descriptive data on the outcome measures but did not conduct statistical analyses. The pilot data showed that all three active VR games had average heart rates consistent with moderate intensity (46 – 64% HRmax) or higher. Hot Squat had the highest RPE value, followed by Holopoint, Fruit Ninja, and Portal Stories, respectively. Interestingly, participants were able to choose the amount of time each game was played (between two and ten minutes). Participants played Hot Squat for the lowest amount of time (6:43 + 2:42) while the other games were played for the maximal time allowed. It was noted that participants became fatigued quickly during Hot Squat as lower-body muscles were primarily used in rapid squatting motions. Because no statistical analyses were performed on the collected data, the data must be viewed with caution and conclusions regarding the impact of the VR games on physiological and perceptual variables are limited (Yoo et al., 2017).

Gomez et al. compared the physiological effects of three VR games in forty-one healthy younger adults. The system used included the HTC Vive headset with controllers, and two cameras that create the play space for the user. Games included “Audioshield” (music-oriented game where the player blocks incoming orbs), “Thrill of the Fight” (controllers simulate boxing gloves while facing against an opponent), and “Holopoint” (controllers simulate a bow and arrow to shoot distant and incoming targets). Participants played each game for ten minutes while oxygen consumption (VO2,), heart rate, and RPE (collected at fourth, sixth, and eighth minute) were collected. Results showed that all games had higher physiological measures than resting values. Based on METS categorization, both Audioshield and Holopoint fell within moderate intensity (3 - <6) while Thrill of the Fight fell within vigorous intensity (>6). Interestingly, RPE values for both Audioshield and Holopoint were towards the lower end of the Borg scale, with values ranging from 9 – 11 (Light), while MET intensity levels were consistently in the moderate range. Similarly, RPE values during Thrill of the Fight were consistent with moderate intensity (11-13), while METS were in line with vigorous intensity. Virtual reality gaming focuses on allowing participants to become immersed in the virtual environment. If VR provides sufficient distraction and is perceived as enjoyable, perceived effort during gameplay may be lower while still maintaining higher intensity levels (Pasch, Bianchi-Berhouze, Dijk, & Jijholt, 2009). These findings may suggest that users could play active VR games for longer durations to accumulate physical activity that matches recommended guidelines before becoming fatigued too quickly (Gomez et al., 2018).

Summary

Active gaming studies have established that older and new AG technologies have games that allow users to reach moderate intensity activity while playing at self-selected levels, independent of prior gaming experience. Active games that incorporated whole-body or lower-body movements generally lead to higher energy expenditures and intensity levels compared to games that primarily relied on upper extremity movements. While AG research has significantly grown in the past two decades, some limitations in the field exist. For example, little is known on how individual proclivities to game genres could impact intensity levels achieved during gameplay. Furthermore, the current research demonstrates that different game genres or games have different impacts on physical activity intensity during gameplay. However, AG studies are limited in grossly applying findings with all active game genres across multiple gaming platforms as a relatively small selection of games have been studied.

VR is the latest iteration of gaming technology that allows users to be physically active while achieving game objectives. Based on the preliminary evidence, VR could offer an advantage over prior active gaming systems. Specifically, VR could provide greater levels of immersion that allow participants to reach higher intensity levels while perceiving lower exertion during gameplay. However, more research needs to evaluate this interaction between game immersion and perceived and actual physical activity intensity levels. Prior gaming technologies, including Xbox Kinect and Nintendo Wii, may soon be outdated gaming platforms as new gaming technologies provide alternative means to playing video games. To date, very few studies have assessed VR's effects on physical activity intensity. Similar to AG studies, several VR games currently exist, and a very small subset of VR games is represented in the literature. Therefore, more research focusing on VR systems and specific VR games needs to be conducted.

Emotional Responses to Active Gaming

Active gaming has the potential to increase physical activity while also providing a source of entertainment. Thus, another major component associated with active video games is the enjoyment or positive emotions that are present when playing said games. Positive emotions present during acute bouts of exercise can be a predictor of future participation in physical activity (Williams, 2008). Because traditional forms of activity can become monotonous or repetitive, individuals may perceive healthy activities such as walking, running, or jogging, to be boring and therefore lead to physical inactivity (Geiwitz, 1966). Depending on the individual nature of the active game (i.e. game genre, game movements, game objectives, etc.), enjoyment levels could promote adherence or regular involvement in the activity (P. Ekkekakis, Parfitt, & Petruzzello, 2011). While the prior section evaluated various measures of physical activity intensity during active gaming, the current section will focus on the emotional responses to these gaming technologies.

Active gaming research has used various methods of evaluating emotional responses to active games. One method is the Visual Analog Scale (VAS) (Moholdt, Weie, Chorianopoulos, Wang, & Hagen, 2017; Naugle et al., 2019; K. E. Naugle et al., 2014). The VAS uses an eleven-point scale to measure enjoyment level for a given activity and it ranges generally from zero (least enjoyable) to ten (most enjoyable). Another method of evaluating emotional responses is the Physical Activity and Enjoyment Scale (PACES). The original PACES form includes 18 items which ask questions relating to various emotional responses to a given activity. However, many questions on the form range in topic from affective balance to life fulfillment. In lieu of using the full version, a modified PACES was used specifically for acute purposes within AG. This version includes questions that directly relate to acute enjoyment during a specified physical activity (Graves et al., 2010). Although not as common as the previous tools, other emotional response assessments used within the AG literature include the Intrinsic Motivation Inventory (IMI), the Positive and Negative Affect Schedule (PANAS), and the Subjective Exercise Experience Scale (SEES). These inventories include similar Likert-style questions asking for various emotional responses to physical activity.

Enjoyment within Active Gaming: Systems using Controllers

Initial AG research evaluating emotional responses focused on older PlayStation systems. In a previously mentioned study by Sell et al., college participants with varying levels of playing experience completed a continuous 30-minute bout of the once popular

Dance Dance Revolution (DDR) game for the PlayStation 2 system. In addition to the physiological variables collected, participants were asked to rate their enjoyment level during game play using a scale ranging from 1 (not enjoyable) to 5 (highly enjoyable). For both groups, enjoyment was higher during DDR gameplay than during self-selected treadmill walking. When evaluating how prior gaming experience affected enjoyment, the experienced group enjoyed the DDR session more than the inexperienced group. While the authors did not hypothesize why experienced players enjoyed the active game more than then inexperienced group, it may be due to possible mechanisms such as greater relaxation, less gameplay anxiety, and an improved ability to focus and successfully complete game tasks (Sell et al., 2008).

Most active gaming research assessing emotional responses to these games has focused on the Nintendo Wii system. For example, Mullins et al. evaluated the physiological and perceptual responses to Wii Fit games in young adults. By using a modified version of PACES, enjoyment levels were compared among four categories of Wii games (aerobic, yoga, balance, and strength). The results indicated that enjoyment ratings were higher during the aerobic and balance-based games than during the strength games (Mullins et al., 2012). Graves et al. also compared physiological and psychological responses to similar game categories in healthy adolescents, young adults, and older adults. By using the modified PACES, participants rated Wii muscle conditioning, Wii aerobics, and Wii balance more enjoyable than handheld gaming. Participants also rated Wii aerobics and Wii balance games as more enjoyable than treadmill walking and treadmill jogging. Notably, Wii aerobics was the only active game to elicit energy expenditure in the moderate intensity range. Considering that repetitive movements can lead to boredom, the irregularity of game movements during the active games compared to walking and jogging could have contribute to higher enjoyment levels in the active games (Graves et al., 2010).

Perron et al. compared the physiological and psychological responses in young, healthy adults while treadmill walking and playing Wii "Island Cardio Blast" for "EA Sports Active." Participants were asked to rate their enjoyment level using the 18-point PACES after a 40-minute bout of the Wii game and after a 30-minute bout of self-selected treadmill walking. Participants enjoyed "Island Cardio Blast" (99.7 + 18.) more than treadmill walking (84.0 + 17.8). Besides enjoyment, affect was measured using the Feeling Scale (FS) (Hardy & Jack Rejeski, 1989) and the Felt Arousal Scale (FAS) (Svebak & Murgatroyd, 1985) before, during, immediately after gameplay, and twenty minutes after gameplay. The FS measures affective responses (i.e., pleasant/unpleasant) during exercise with a bipolar 11-point scale ranging from "very bad" to "very good". The FAS is a 6-point scale ranging from Low to High arousal. The results showed similar changes in FS and FAS in both treadmill walking and active gameplay with affect and arousal scores being higher during, immediately after exercise, and twenty minutes after activity when compared to pre-activity values. The high levels of enjoyment and positive affect during and after active gameplay suggests that the AG "Island Cardio Blast" could be a mode of physical activity that promotes higher adherence when compared to traditional physical activity modes. However, what is not known is whether this enjoyment trend persists following repeated active gaming bouts. Longitudinal studies would be necessary to evaluate whether this phenomena is present over time (Perron et al., 2012).

Among physiological variables, Naugle et al. also compared affective outcomes in young healthy adults while playing four Wii games (Tennis, Boxing, Step, Cycle) and completing two traditional aerobic activities at self-selected intensities (Bike and Treadmill). Participants completed the Positive Affect Negative Affect Schedule (PANAS) before and after each 20-minute bout of activity. The PANAS measures both positive and negative affect using Likert-style questions with 10 positive items and 10 negative items (Watson & Clark, 1988). Participants also rated their enjoyment after each activity using an 11-point VAS. Results showed that positive affect decreased following both traditional aerobic activities, while positive affect increased after playing Wii tennis and Wii boxing. Negative affect scores for all activities decreased after each activity. Wii boxing was rated more enjoyable than biking and treadmill walking, and Wii Tennis was rated more enjoyable than all the other active games (K. E. Naugle et al., 2014). While Wii Tennis and Boxing elicited higher enjoyment and positive affect compared to the traditional exercise, differences in exercise intensity and the instructions given to participants during the activities (i.e., prescribed moderate pace for traditional exercises vs. self-selected intensity for active games) could have confounded these results.

Similarly, Douris et al. also compared Nintendo Wii aerobics games to treadmill walking in sedentary young adults. Participants completed thirty-minute bouts of treadmill walking set at 3.5 miles per hour and a bout of "Free Run" for Wii. By using the Subjective Exercise Experience Scale (SEES), participants rated their positive well-being, psychological distress, and fatigue before and after each activity. Psychological distress decreased during both Wii gameplay and treadmill walking while both conditions saw a comparable increase in feelings of fatigue (Douris et al., 2012). Interestingly, positive well-being increased during treadmill walking while it decreased during Wii gameplay. One potential explanation for this unexpected result could be that participants played the Wii Fit game at a higher physiological and perceived intensity compared to the treadmill walking. The authors hypothesized, based on prior research, that individuals who are sedentary may perceive more intense exercise in a negative manner (Blanchard, 2001; P. Ekkekakis, 1999; Focht, Knapp, Gavin, Raedeke, & Hickner, 2007).

While several studies have assessed enjoyment and affective responses to playing Nintendo Wii games, little is known about future intent in playing active games regularly. To address this gap in the literature, Garn et al. evaluated physical activity levels, enjoyment, and future intentions of playing Nintendo Wii Fit games in physically inactive college-aged students. Participants played five Wii games which fit into either aerobic (Basic Run, Basic Step) or balance (Ski Slalom, Balance Bubble, Table Tilt) categories. The researchers assessed perceived enjoyment and intention for generic activity prior to playing the Wii games by using a modified PACES and a future intentions question which ranked the likelihood of participating in a given activity via a five-point Likert scale. Each game was played for ten minutes followed by completing the same enjoyment and intention tool relating to the Wii gaming bouts. Participants perceived Wii games (4.27 + 0.46) more enjoyable than generical physical activity (4.05 + 0.70) and also found that if given the opportunity, participants' future intention to play Wii games again (4.33 + 0.76) was higher than intent to participate in generic physical activity (3.67 + 0.92). This difference in future intentions between these activity modes suggests that, for a sedentary young adult population, participating in active games like

Wii Fit compared to traditional exercise could promote more regular physical activity participation (Garn, Baker, Beasley, & Solmon, 2012).

Given that many active games only elicit light to moderate physical activity, one group of researchers recently attempted to create an exergame that implemented enjoyable high-intensity interval training. Specifically, Moholdt and colleagues created a new online multiplayer active game (Pedal Tanks) using a stationary bike and computer. In this game, two teams of two aim to capture the opponents' flag. Participants would pedal on the stationary bike and use buttons located on the handlebars to control a tank and outmaneuver the other team. As a control condition, participants completed an outdoor walking activity at a self-selected intensity in groups of four (similar to the "Pedal Tanks" gaming session). Participants were instructed to play both activities for at least fifteen minutes, but no longer than one hour. By using a 11-point VAS, participants rated the "Pedal Tanks" game (8.7 + 0.1) as more enjoyable than the walking activity (3.9 + 1.8). These enjoyment findings were supported by the amount of time spent in each activity, with time playing the active game (44.3 + 0.7 minutes) being higher than walking (17.0 + 0.7 minutes). The authors suggested that the competitive nature of the game, along with the teamwork component, could account for both the higher levels of enjoyment as well as the amount of time spent participating in the game (Moholdt et al., 2017). Overall, this newly developed game elicited high intensity exercise and was perceived as highly enjoyable in young adult males.

Enjoyment through Active Gaming: Systems with no Controllers

Only one study solely using a system without controls, the Xbox Kinect, has evaluated emotional responses to active gameplay. Yang et al. measured moderate-to-vigorous physical activity and enjoyment levels in sedentary college participants while playing the "Break a Sweat" activity in the "Your Shape Fitness Evolved 2012" game. After playing a thirty-minute bout at a self-selected intensity, participants were asked three five-point Likert questions relating to the active game. The questions asked about their enjoyment during gameplay, the likelihood of using active games as a mode of exercise in the future, and if they would use the game to meet recommended exercise guidelines. Overall, participants perceived the Kinect game enjoyable with eighty percent responding that if they had access to the console and game that they would use it as exercise in the future. Sixty percent responded that under similar circumstances they would use active games to meet physical activity guidelines (C. Yang et al., 2014). Importantly, this is the second study revealing positive future intentions to use active gaming in the future for exercise in sedentary individuals.

Enjoyment through Active Gaming: Comparing Gaming Systems

Some research has compared emotional responses to active gaming across systems utilizing controllers against systems requiring no controllers. Duncan et al. compared different gaming systems to traditional treadmill walking in healthy young adults by measuring physiological and psychological effects. Thirty participants completed four activities, including sedentary gaming (Fifa football 2010) using a handheld controller, Just Dance on Nintendo Wii, Fifa football while stepping on the Gamercize Power Stepper to power the controller, and self-selected treadmill walking.

All participants reported either owning one or both gaming systems and having familiarity with the games played for the study. Participants performed each activity for ten minutes with the modified PACES given after each activity to rate enjoyment. The results indicated that enjoyment was higher during active gameplay than during brisk treadmill walking. Males reported higher enjoyment during the Nintendo Wii activity, Gamercize game, and sedentary game compared to treadmill walking. Females reported highest enjoyment levels during Nintendo Wii Just Dance compared all other activities. These findings suggest that both sexes may enjoy playing these games as a mode of physical activity, with perhaps different game preferences between males and females (M. Duncan & Dick, 2012).

Lyons et al. evaluated physiological and psychological differences in energy expenditure and enjoyment across four game types (shooter, band simulation, dance, and fitness) across three different gaming platforms (Xbox Kinect, Playstation 3, and Nintendo Wii). Shooter games were played on the Wii or Playstation system, band and dance games were played on the Kinect, and fitness games were played on the Nintendo Wii. Participants played games within each category for thirteen minutes with rest periods between bouts. Participants rated their enjoyment levels by using the enjoyment subscale of the Intrinsic Motivation Inventory, in which participants rank agreement to various emotional statements using Likert-style questions. Band and dance games were found to be more enjoyable than the other games but failed to produce intensity levels consistent with physical activity guidelines. However, if mechanisms were introduced to make this game type more strenuous, it could at minimum promote light physical activity (Lyons et al., 2014).

In a previously mentioned study, Naugle et al. evaluated whether adding structured instructions to maximize movement during active gameplay would increase physiological outcomes and elicit different psychological responses compared to game play at a self-selected intensity. Twenty-one healthy young adults played four active games across two gaming platforms (Xbox Kinect and Nintendo Wii) for two fifteen-minute bouts, with one bout at a self-selected intensity and one with structured instructions to maximize body movement. Participants played a boxing and tennis game on each gaming system (Kinect Boxing, Kinect Tennis, Wii Boxing, Wii Tennis) and ranked their enjoyment using an 11-point VAS after each game bout. The Kinect Boxing game had the highest enjoyment ratings among all the games, regardless of game instructions. Participants had higher enjoyment and energy expenditure during structured game bouts compared to self-selected gameplay. A possible explanation for this finding was that these participants reported regular physical activity participation and thus, may have enjoyed the active games at a more vigorous pace than playing at self-selected intensities. Another explanation for the enjoyment differences was that the order of the self-selected intensity period and structured instructions period was not randomized. Because the structured period always followed the self-selected intensity period, game familiarization may have led to higher enjoyment. (Naugle et al., 2019).

Summary

In summary, the evidence suggests that playing active video games elicit relatively high enjoyment levels and positive emotions in young healthy adults, regardless of gaming system. Active gaming studies also show that young adults generally enjoy active games and have higher intentions to do future active gaming more than traditional modes of activity like treadmill walking. However, the evidence also indicates that enjoyment and emotional responses to games likely vary by type of game, active gaming experience, and fitness/activity levels of participants. Furthermore, it must be noted that only a subset of all active video games is represented and that these findings may not translate to games not studied. In addition, only one study evaluated sex differences between different game types, suggesting that enjoyment of different games may differ between males and females. Game genre may play a role in different emotional responses between sexes. Lastly, most studies have focused on systems that are now outdated technologically. Because VR technology is relatively new, no research to date has evaluated emotional responses to playing VR games. Thus, future research needs to be conducted to evaluate such effects.

Virtual Active Games to Induce Hypoalgesia

The purpose of this section is to provide a foundation for the hypothesis that virtual active games will exert a temporary hypoalgesic effect (i.e., reduction of pain sensitivity and perception) in healthy adults. An introduction to the phenomenon of exercise-induced hypoalgesia will first be provided, followed by a review of the evidence focusing on the hypoalgesic effects of active games in healthy adults. Then, a review of the hypoalgesic effects of virtual reality on experimental pain in health adults will be provided. The initial focus will be on the effects of passive VR (little to no physical activity) on experimental pain followed by a review of the evidence underlying the possibility of a synergistic effect of physical activity and VR (i.e., active VR games) on acute pain sensitivity.

Exercise-induced hypoalgesia

A large body of evidence indicates that acute bouts of physical activity and exercise produce a hypoalgesic effect in healthy adults as well as chronic pain populations (K. M. Naugle et al., 2012; K. M. Naugle, Naugle, Fillingim, Samuels, & Riley, 2014). Specifically, the research demonstrates that an acute bout of aerobic, isometric, or dynamic strength training exercise can reduce pain sensitivity or perception to experimentally induced pain (K. M. Naugle et al., 2012). This phenomenon is known as exercise-induced hypoalgesia (EIH) (Koltyn, 2002). In healthy, pain-free adults, EIH generally follows after an acute bout of exercise that is moderate to vigorous in intensity with a duration of at least 15 to 20 minutes (Kemppainen, Paalasmaa, Pertovaara, Alila, & Johansson, 1990; K. M. Naugle et al., 2012).

Past research suggests that EIH post exercise may be produced by local and central pain inhibitory effects and these effects may be stronger when both effects are combined. Local effects are characterized by reductions in pain in the active or exercising limb. Central effects are characterized by pain reductions in body parts distant to the exercising muscle (Gomolka et al., 2019). Research has shown combined local and central pain inhibitory effects during aerobic activities (Micalos & Arendt-Nielsen, 2016; K. M. Naugle et al., 2012; Vaegter, Dorge, Schmidt, Jensen, & Graven-Nielsen, 2018; Vaegter, Handberg, & Graven-Nielsen, 2014) and isometric exercises (Koltyn, Brellenthin, Cook, Sehgal, & Hillard, 2014; Kosek & Lundberg, 2003; K. M. Naugle et al., 2012; Vaegter et al., 2014). Several mechanisms have been proposed to underly these local and central effects for EIH. Mechanisms include changes in attention, changes in ß-endorphins, changes in plasma adrenaline and noradrenalin, peripheral nociceptive inhibition, and expressed endogenous opioid substances located both centrally and locally during and after exercise (Kosek & Lundberg, 2003; Micalos & Arendt-Nielsen, 2016; K. M. Naugle et al., 2012; Tegeder et al., 2003; Vaegter et al., 2014).

Exercise-induced Hypoalgesia through Active Gaming

As previously mentioned, EIH is typically induced by continuous moderate to vigorous aerobic exercise that lasts at least 15 minutes. However, this type of traditional aerobic exercise may not be suitable for deconditioned individuals or may not be feasible for those with pain conditions. Alternatively, active gaming may be a suitable alternative to traditional exercise for the aforementioned populations as gameplay can voluntarily be intensified or adjusted to player needs. These active games also provide intermittent breaks which give rest periods to participants as well as minimize strenuous gameplay. Thus, recent active gaming research investigated whether active games could produce a sufficient level of physical activity to produce EIH and potentially be a pain management tool.

In one of the first studies examining the hypoalgesic effects of active gaming, Naugle and colleagues evaluated AG as a mode of pain relief for delayed onset muscle soreness in college-aged participants. Participants completed an isotonic eccentric exercise protocol to elicit delayed onset muscle soreness (DOMS) in the non-dominant biceps brachii. Twenty-four and 48 hours post eccentric exercise, participants completed one of three 20-minute interventions to reduce DOMS or a control condition (no intervention). The interventions included ice therapy, Wii Sports Boxing played at self-selected intensity, and light standardized flexion/extension exercise of the affected arm. All outcome measures were assessed before and immediately after the 20-minute intervention sessions. Results showed that pressure pain sensitivity, pain during elbow flexion and extension, and pain-free range of motion during elbow flexion improved only after the Wii Boxing intervention. Thus, Wii Sports Boxing had the greatest hypoalgesic effect in temporarily reducing pain sensitivity and pain during movement of the affected arm compared to the other interventions. The Naugle et al. study did not measure exercise intensity during Wii Boxing; however, several other studies indicate that Wii boxing typically elicits an upper light to moderate intensity of physical activity when played at a self-selected intensity. In sum, the Naugle et al. study provided the first evidence that Wii Sports Boxing at a self-selected intensity could induce EIH (K. E. Naugle et al., 2017).

More recently, Carey et al. evaluated the hypoalgeisc effects of playing four active games (Wii Boxing, Wii Tennis, Kinect Fighter Within, and Kinect Tennis) in young healthy adults. While wearing hip-accelerometers, participants played two fifteen-minute bouts of each game with the first bout played at a self-selected intensity and the second bout played with instructions to maximize whole-body movement. Pressure pain thresholds (PPT) were assessed on the left forearm and upper right trapezius muscle and heat pain thresholds (HPT) were assessed on the left forearm before and after each active gaming bout. Results showed that pressure pain sensitivity decreased after playing Kinect Fighter Within and Wii Boxing (i.e., increased PPT), while no significant difference was observed after playing Kinect Tennis and Wii Tennis. The accelerometer data indicated that significantly more time was spent in moderate-to-vigorous activity for Kinect Fighter Within and Wii Boxing compared to the other tennis games. Furthermore, the accelerometer data showed across all games 1) a positive association between moderate-to-vigorous intensity activity and EIH measured with pressure pain thresholds and 2) a negative association between sedentary time and EIH measured with pressure pain thresholds. As such, a primary factor determining whether an active game elicits EIH is likely the intensity level reached during game play. Notably, however, both Kinect Fighter Within and Wii Boxing reduced pain sensitivity even though approximately half of game play was spent in whole-body light physical activity or sedentary time (Carey et al., 2017). Overall, this study suggests that active games can produce EIH in healthy adults without long bouts at high intensity levels.

In summary, the first two studies evaluating AG and EIH revealed that playing these games can produce a hypoalgesic effect in two different models of experimental pain. Based on the promising results of these initial studies, future research should explore active gaming as a viable exercise option for those with pain conditions. Given the interactive nature of active games, it is possible that active games could serve as a pleasant distraction from pain symptoms in individuals with chronic pain and thereby enhance compliance with exercise therapy. However, future research needs to test this hypothesis.

The Hypoalgesic Effects of Virtual Reality

Research on VR as a method of pain reduction has significantly grown in the past two decades. Thus far, the research suggests that passively engaging in VR (little-to-no physical activity) has a positive effect on acute pain sensitivity in healthy adult populations as well as clinical populations (Glennon et al., 2018; Jin et al., 2016; Law et al., 2011; Magora et al., 2006). The original underlying mechanism that supports VR's ability to provide pain relief relies on distraction. This distraction theory suggests that if focus is driven from pain to some other external stimulus, then the pain stimulus will not be perceived as painful. In other words, sensory systems have limited capacity for concentrating on painful stimuli if other external stimuli are drawing the attention of the individual (H. G. Hoffman et al., 2007; McCaul & Malott, 1984). The following paragraphs will focus on reviewing the literature evaluating the hypoalgesic effects of VR on experimental pain in healthy adults. Most of this research has focused on VR games that involve little to no physical activity.

Boylan et al. evaluated how different types of distraction affected pain and discomfort during a leg lift in healthy adults. Participants completed an isometric leg lift during three separate conditions, each including a different gaming scenario. Scenarios included 1) a video game where participants played an action game on a monitor, 2) a video clip of pre-recorded gameplay in which the participant would watch, 3) a VR headset-based game which allowed freedom to explore the virtual environment, and 4) a baseline condition with participants focusing on a fixed cross-display in front of the participant. The duration of the leg lift was considered to be the index of pain tolerance as no other incentives were given and subjective discomfort level was measured using a VAS. Participants scored highest discomfort levels during baseline and lowest during the VR condition. The video game condition elicited the highest pain tolerance with the longest duration of the leg lift sustained, followed by the VR condition. Overall, the video game with an interactive component (i.e., playing the video games in a seated position) and passive VR were more effective in distraction from bodily discomfort than the other scenarios (i.e., watching video clip and baseline) (Boylan, Kirwan, & Rooney, 2018).

Magora et al. implemented a similar protocol evaluating VR immersion on experimental ischemic pain in healthy adults. Participants completed two separate sessions, one with a VR headset and one without VR. To induce pain, participants wore a blood pressure cuff with fixed pressure on the forearm. During both VR and non-VR conditions, participants would indicate when pain first became intolerable, which would be an index of pain tolerance. For the VR condition, participants used a thumb joystick to play a game shooting targets, and the non-VR condition involved sitting quietly with no VR headset worn. The results indicated that sex differences were present in both conditions with men having higher pain tolerance (i.e., more time) than women for both VR and non-VR conditions. However, pain tolerance between conditions was higher during the VR compared to the non-VR for both sexes (Magora et al., 2006).

Hoffman et al. also evaluated the effects of VR distraction on ischemic pain. Twenty-two healthy young adults participated in two separate phases; a non-VR phase immediately followed by a VR condition. The non-VR phase included sitting quietly with no VR helmet for 8 minutes. During the 8 minutes, pain was experimentally induced during each phase by using a tourniquet on the upper arm. The participant elevated the left arm for one minute, after which the tourniquet was inflated. The participant returned the arm to a horizontal resting position on a table, which marked the beginning of ischemia. Every two minutes, participants would rate their average pain and worst pain using a VAS. For those that could tolerate the 8 minutes of ischemic pain, a VR phase immediately followed the non-VR phase. The VR phase included wearing a head mounted display system in which participants engaged with a virtual kitchen environment for 2 minutes. Results showed that pain increased significantly throughout the non-VR condition. After applying the VR headset to those who tolerated eight minutes of no VR, average and worst pain ratings significantly decreased. Results from this study suggest VR has an acute hypoalgesic effect on pain intensity through distraction and that VR could serve as a useful pain reduction technique for those who suffer from pain (H. Hoffman et al., 2003). Taken together, the Hoffman and Magora studies provide evidence that VR can be used primarily as a distraction tool for pain in both men and women.

While previous studies evaluated VR as a distraction tool in pain management, Czub et al. evaluated the relationship between arm movement during VR and pain experience. While wearing a VR headset, participants played a game using a computer mouse as a controller. Participants played a space game where they would control an avatar to collect white spheres and avoid red spheres. To compare movement differences, two game conditions for VR were implemented where one game required small mouse movements with the other requiring large mouse movements to achieve the same game objectives. Large movements required eighty times greater physical movement to elicit the same effect in the small movement condition. Full screen horizontal movement required forty-two centimeters of physical movement, with vertical movement requiring fifty centimeters. For screen movement in the small movement condition, 0.5 cm of horizontal movement and 0.6 cm for vertical movement was required. During these two conditions and a non-VR control condition, participants placed their non-active hand in a cold-water bath. Participants were instructed to remove their hand from the water when the pain became unbearable. The amount of time spent in the cold water represented pain tolerance and participants rated their pain intensity using a 11-point VAS scale with zero as “no pain” and ten as “extreme pain.” In both movement conditions, pain tolerance was higher than the non-VR condition, but no differences were observed between movement conditions. Pain intensity during large-movement VR was lower than during small-movement VR. Results from this study suggest that larger movements during VR gameplay may be associated with higher reductions in pain intensity. However, considering that this protocol utilized single arm movement, more research needs to be conducted on whether larger-limb movement or whole-body movement, along with VR immersion, may induce greater pain outcomes in healthy adult populations (Czub & Piskorz, 2017). The Czub study is one of the first to suggest an additive hypoalgesic effect when combining VR with movement.

Hayashi et al. compared the hypoalgesic effects of VR combined with exercise imagery to VR distraction. VR with imagery incorporated a head-mounted display which projected a first-person point of view video clip on a road while participants were asked to imagine that they were running during the session. VR distraction used the same video clip, but participants were asked to imagine that they were driving a vehicle on the road instead of running. A pressure pain threshold test was performed on the left quadriceps muscle and the right dorsal forearm before, during, and after the VR task. VR combined with exercise imagery resulted in a higher pressure pain threshold during the VR task when compared to VR distraction regardless of the participants' imagery abilities (Hayashi et al., 2019). Prior research indicates that exercise imagery increases brain activity in the motor and premotor cortex similar to if actual movements were occurring (Lotze & Halsband, 2006; Miller et al., 2010) and thus may introduce another mechanism through which pain could be decreased. The Hayashi study provides additional preliminary evidence that hypoalgesia could be enhanced when the distraction effects of VR are combined with hypoalgesic effects of exercise.

Summary

VR has been shown to reduce pain sensitivity in healthy young adults. Studies have shown how VR has affected pain sensitivity through individual components, such a distraction, body movement, and imagery. Less is known on how whole-body physical activity during VR gameplay influences pain sensitivity and whether there is an enhanced effect when combining whole-body movements and VR distraction. Thus, more research is needed specifically to address how physical activity, not just exercise imagery, affects pain sensitivity in young healthy adults playing VR games.

Future Research

Because VR is a relatively novel gaming technology, the effects of VR games on physical activity intensity levels remains unknown. Currently, only one peer-reviewed study has evaluated the intensity levels reached while playing VR games at self-selected intensity. Future research should start to evaluate how VR technology can influence physical intensity levels, potentially starting with healthy populations and then progressing to different populations such as those with pain conditions. Findings from future research could support VR as an alternative approach to participating in physical activity. More specifically, future research could start to evaluate specific VR games and build a literature base similar to what has been done in the literature evaluating prior active gaming technologies.

Physical activity participation requires alternative modes that are perceived to be enjoyable or pleasant. Prior active gaming research shows that this mode of physical activity can be more enjoyable than traditional aerobic activities. With this backing, future research should start to focus on emotional responses, like enjoyment, while participating in VR gaming. Currently, there is little research specifically looking at emotional responses to VR gaming. Again, the novelty of VR technology has not allowed for a better understanding of how VR affects emotional responses during participation.

Finally, the effects of physical activity and exercise on pain sensitivity are well-documented. Compared to the prior sections, less is known on how active gaming technologies affect pain sensitivity in young, healthy adults. The few studies that have been conducted used older systems (Kinect and Nintendo Wii) with initial results showing a hypoalgesic effect. Research in the past decade also indicates that passive and interactive VR with little to no movement affects pain sensitivity, likely through a mechanism of distraction. However, little is known on how the combination of physical activity and distraction via VR affects pain sensitivity or whether an enhanced hypoalgesic effect is present when playing active VR games. Future research should focus on the effects of different physical activity levels and movement intensities in pain modulation while engaged in VR. Findings from future studies could impact pain treatment and management in populations that suffer from pain conditions.

CHAPTER 3

METHODS

Research Design

This study used a repeated-measures design where all participants played each VR game. The order of the games was randomized and counterbalanced. Physical activity intensity was measured continuously during gameplay, while enjoyment of playing games and ratings of perceived exertion (RPE) were measured immediately after each game. Pressure pain sensitivity on the lower and upper extremities were assessed pre- and post-game play. By determining levels of physical activity, enjoyment, and hypoalgesia elicited by the different games, suggestions could be made for which games were most effective for positive outcomes.

Participants

Following approval by the Institutional Review Board, thirty-six (36) adults between the ages of 18 and 30 were enrolled in and completed this study between January 2020 and August 2020. An equal number of males and females were enrolled. Participants were recruited from Indianapolis and the surrounding areas through flyers, word of mouth, and a verbal script presentation. Interested participants were instructed to contact the researcher through email to inquire about study eligibility and schedule the first session appointment. All participants were fully informed of the nature of the study and their right to decline participation or withdraw from participation at any point of time. Written informed consent was obtained from all participants. Thirty-nine (39) participants were enrolled in the study, but three participants were unable to complete all study sessions due to events surrounding the COVID-19 epidemic. Only data from participants who completed the entire study was included in the data analysis.

Inclusion Criteria. Inclusion criteria included individuals who were between the ages of 18 and 30 years.

Exclusion Criteria. Exclusion criteria for this study included (a) prior or current experiences with motion sickness or claustrophobia, (b) an answer of "Yes" on any of the seven general 2019 Physical Activity Readiness Questionnaire (PAR-Q) items and on the subsequent follow-up questions, (c) and any acute or chronic pain condition. The PAR-Q form asks whether a participant is physically able to perform physical activity and includes the following: 1) if the participant's doctor has ever said that he/she has a heart condition and that he/she should only do physical activity recommended by a doctor, 2) if the participant has chest pain when doing physical activity, 3) if in the past month, the participant has experienced chest pain when not doing physical activity, 4) if the participant has ever lost balance because of dizziness or has ever lost consciousness, 5) if the participant has any bone or joint problem that could be made worse by change in physical activity, 6) if the participant is currently on prescribed drugs for blood pressure or any heart condition, and 7) if the participant knows of any other reason why he/she should not do physical activity.

Session Exclusion Criteria. Session exclusion criteria included (a) severe uncontrolled hypertension (resting SBP > 180mmHg, resting DPB > 99mmHg), (b) vigorous exercise performed within 12 hours of the scheduled session appointment, (c) a fasting period of at least one hour, (d) smoking or alcohol consumption within 24 hours of scheduled session, (e) caffeine ingested on day of session prior to appointment, (f) any analgesic medications taken on the day of the session prior to appointment, and (g) not wearing clothing which allows skin contact for PPT trials on the dominant thigh and forearm.

Procedures

Eligible participants interested in the study completed four sessions. The first session included the informed consent process and one experimental game. Sessions 2 –4 were devoted to one experimental game per session. All sessions were conducted in the National Institute for Fitness and Sport, located on the IUPUI campus. See Figure 1 for study design.

Figure 1. Study Design

Session 1	Session 2	Session 3	Session 4
ICF, Screening, Resting Measures, VR & PPT Familiarization -- -- -- -- -- -- -- -- -- - PPT - Game Familiarization - 15 min of VR game - RPE - Enjoyment rating o Modified PACES o VAS	- Resting HR - PPT - Game Familiarization - 15 min of VR game - RPE - Enjoyment rating o Modified PACES o VAS	- Resting HR - PPT - Game Familiarization - 15 min of VR game - RPE - Enjoyment rating o Modified PACES o VAS	- Resting HR - PPT - Game Familiarization - 15 min of VR game - RPE - Enjoyment rating o Modified PACES o VAS

Screening and Enrollment (Session 1). Individuals interested in participating in the study were given a brief description of the study purpose as well as the equipment used during the sessions. Participants were also given a brief overview of the study procedures. If still interested in participating, participants were asked to read and sign an Informed Consent Form (ICF) and a copy of the ICF was given to the participant to keep for their records. Following the ICF process, participants were given the Physical Activity Readiness Questionnaire (PAR-Q+ 2019 version) and International Physical Activity Questionnaire (IPAQ) to complete. Height, weight, and resting heart rate (HR), and resting blood pressure were collected. Participants were also asked to fill out a demographic questionnaire. Questions included the following items: 1) right or left-handed, 2) race, 3) sex, 4) experience or proneness to motion sickness or claustrophobia, 5) currently experiencing acute or chronic pain, and 6) experience playing VR games. Based on exclusion criteria, if the participant affirmed a prior history or susceptibility for either symptom or condition, the participant was excluded. If any exclusion criteria relating to the PAR-Q+ form became present after its completion (See Exclusion Criteria), the participant was excluded. Session exclusion criteria was evaluated at the beginning of each experimental session. If the session exclusion criteria were not met, then the session was rescheduled.

Familiarization of Pain Test and VR system (Session 1). After study eligibility had been confirmed, participants were given a more thorough explanation of the study purpose and procedures. Then, participants underwent a familiarization with the pressure pain threshold (PPT) test to measure pain sensitivity (See outcome measure below for description of test). The PPT test was performed as practice on the participants' non-dominant forearm and ipsilateral thigh three times. Following PPT familiarization, participants were shown the HTC Vive system (HTC, Taiwan; Valve, Washington), which includes a head-mounted display system and two handheld controllers. This VR system uses room-scale tracking technology, which allows the user to move in three-dimensional space and use motion-tracked controllers to translate real-life motion into the VR environment. Two ceiling-mounted sensors mapped the physical space in which the participant played and provided boundaries which informed the user to stay within the designated play area. The HTC Vive system came with a tutorial program which exposes the user to the basic functions of the VR system. Each participant was fitted with the headset and followed the tutorial for movement/system familiarization.

Experimental Protocol (All Sessions). Participants completed four randomized experimental sessions. An overview of the procedures during each session are shown in Figure 1. One of the following four VR games were played during each session: Relax Walk VR, Beat Saber, Holopoint, or Hot Squat. See Table 1 for descriptions of games. Four counterbalanced orders of the games were generated, and each participant was randomly assigned to one of the four game orders, with nine participants per order. Following the familiarization via the tutorial program (only Session 1), participants were introduced to one of the games (which were randomized). A verbal description of the game followed by a visual demonstration was conducted by the researcher for the participant to observe. The participant then played the game for approximately five minutes for familiarization. After five minutes, the participants were asked to stop playing and sit in a resting position to allow for a proper return to resting heart rate.

Prior to playing the game, the participant was fitted with a heart monitor that was worn on the lower portion of the breastbone and syncs with a wristwatch. Three accelerometers were worn, one on the dominant wrist, one on the dominant hip in line with the armpit, and one on the ipsilateral thigh, just above the knee. Additionally, participants underwent a PPT test using a pressure algometer. This was be administered on the anterior side of the dominant forearm and thigh. (See Outcome Measures section above for detail).

Table 1. Virtual Reality Games Descriptions

Game	Description
Beat Saber (Active VR)	Virtual Reality rhythm game where participants use controllers like light sabers that are used to strike incoming objects matched with in-game music
Holopoint (Active VR)	A fast-paced archery game where participants use the controllers as a bow and arrow to hit incoming targets
Hot Squat (Active VR)	A squatting-based game where the participant squats up and down to avoid incoming objects
Relax Walk VR (Non-active VR)	A virtual reality game where participants explore virtual environments by using the controller to transport themselves from place to place. Requires little-to-no upper body movement; can be done sitting or standing.

The participant played the game for 15 minutes. Participants were instructed to play the VR game at his/her self-selected pace. After 15 minutes of game play, the PPT tests were administered twice on the same sites. The participant was then allowed/assisted in removing the VR headset and was asked to rate their level of enjoyment using an 11-point Visual Analog Scale. Participants were asked to rate their average and maximum RPE for the 15-minute session. Then, the next session was scheduled with the participant. Session 1 was expected to last shortly over one hour and Sessions 2 through 4 to last just under one hour.

Instrumentation and Outcome Measures

International Physical Activity Questionnaire (IPAQ). The IPAQ short form (SF) is a measure of physical activity that asks subjects to recall the amount of time during the past seven days spent in vigorous activities, moderate activities, walking, and sitting (Craig et al., 2003; Dinger, Behrens, & Han, 2006). Guidelines provided by www.ipaq.ki.se/ipaq.html were used for data processing and scoring of the questionnaire. Each type of activity was assigned a metabolic equivalent score (MET), which is based on the intensity of that activity. The MET scores were then multiplied by the reported number of minutes per week spent performing that activity, which produced an activity score of METs-minute/week. Scores were calculated for vigorous activity, moderate activity, walking, and Total activity. The test has shown acceptable concurrent and construct validity and test-retest reliability (0.66 – 0.89) (Craig et al., 2003). The IPAQ-SF was administered at the screening session. The IPAQ-SF has been shown to be a valid tool in assessing physical activity participation (Lee, Macfarlane, Lam, & Stewart, 2011).

Polar Heart Rate Monitor. The Polar (FT7) heart monitor was used to measure heart rate during each gaming session. This setup included a monitor strap that is placed on the lower portion of the breastbone and a watch which is synced to the strap. Heart rate values were used to calculate percentages of heart rate reserve (HRR) for interpreting intensity levels. Heart rate reserve was calculated by using the following method: age predicted maximal heart rate (220-age) – resting heart rate. Percentage of HRR during activity was then determined by using the following formula: [(average HR during activity – resting heart rate)/HRR] x 100. The HRR% ranges that were used to determine exercise intensity were 1) Light intensity between 30% and 39%, 2) moderate intensity between 40% and 59%, and 3) vigorous intensity between 60% and 89% (ACSM, 2018; Garber et al., 2011). Using percentages of HRR is a valid and reliable method of measuring physical activity intensity (ACSM, 2018; Strath et al., 2000; Swain, 1997).

Ratings of Perceived Exertion (RPE). After playing each VR game, participants were asked to rate their average and maximal exertion levels using the 6-20 Borg scale where "6" means "no exertion at all" and "20" means "maximal exertion." Ratings given during the sessions should reflect participant perception of physical effort while playing VR games (Borg, 1982). RPE values 9 to 11 are associated with light activity, 12 to 13 with moderate activity, and 14 to 17 with vigorous activity (ACSM, 2018; Garber et al., 2011). The Borg RPE scale has shown to be a valid measure of exercise intensity (Chen, Fan, & Moe, 2002).

Accelerometry. Actigraph GT3X+ accelerometers (The Actigraph Inc. Pensacola, FL) were worn on the dominant wrist, dominant hip, and dominant thigh during all sessions of VR play. The Actigraph is a small lightweight tri-axial accelerometer that is designed to detect tri-axial accelerations in the range of 0.05-2G. Output from the Actigraph was in the form of step counts, body positions and activity counts for a specific time period. Data was captured in 1-second epochs. The accelerometer data used for analyses was calculated from minutes 2 through 14 (13 minutes total) of each 15-minute active gaming period to represent steady-state activity. Activity count cut-points (e.g., counts/min) can be identified to determine the amount of time a subject spends in sedentary, light, and moderate-to-vigorous activity. See Table 2 for physical activity intensity cut points for accelerometer data (Freedson, Melanson, & Sirard, 1998).

Table 2. Accelerometer cut-points for the different categories of physical activity.

Physical Activity Intensity	Accelerometer Cut Points (counts/minute)
Sedentary	<100
Light	100-1951
Moderate	1952-5724
Vigorous	5725-9498

Based on these cut-points, percentage of time spent in whole body MVPA [waist-worn accelerometer: (MVPA minutes/13 minutes)*100], percentage of time spent in whole body light activity [waist-worn accelerometer: (light minutes/13 minutes)*100], and percentage of time spent in whole body sedentary behavior [waist-worn accelerometer: (sedentary minutes/13 minutes)*100] was calculated. The same variables will be calculated for the arm and thigh accelerometers. The Actigraph GT3X+ is a valid and reliable tool and has been used in prior active gaming studies to measure physical activity intensity levels (Aadland & Ylvisaker, 2015; Jones, Crossley, Dascombe, Hart, & Kemp, 2018; Kelly et al., 2013; Kim, Barry, & Kang, 2015; Naugle et al., 2019).

Enjoyment. Upon completion of each game, participants were asked to complete an 11-point visual analog scale (VAS; 10 centimeters in length) indicating their level of enjoyment while playing VR games, with "0" indicating no enjoyment and "10" indicating the most enjoyment one could experience. The VAS (See Appendix A) has been used to measure enjoyment in previous active gaming studies (Moholdt et al., 2017; Naugle et al., 2019). The VAS score measured to the nearest tenth was the value used in statistical analysis.

Participants were asked to complete the modified Physical Activity Enjoyment Scale (PACES), which included five Likert-style questions asking about enjoyment perceived during VR gameplay. Questions on the PACES were seven-point scale items which included rating perceived feelings ranging from 1) enjoy to hate, 2) dislike to like, 3) fun to no fun, 4) feel good physically to feel bad physically, and 5) frustrated to not frustrated. The PACES (See Appendix A) has been used in prior active gaming studies and is a validated tool in measuring enjoyment during physical activity (Dunton, Tscherne, & Rodriguez, 2009; Graves et al., 2010; Kendzierski & DeCarlo, 1991; Moore et al., 2009). Each question had a maximum score of seven (7) with the lowest being one (1) and the highest total score thirty-five (35) and lowest zero (7). The percentage of the sum of the individual questions out of thirty-five for PACES was used in statistical analysis.

Pressure Pain Threshold (PPT). A digital, handheld, clinical grade pressure algometer (Wagner Instruments, Greenwich, CT) was used to assess pressure pain thresholds on the dominant, anterior side of the forearm and thigh. A pressure algometer is a smaller device that has a one-centimeter rubber tip which is placed on the skin surface. The experimenter applied a slow constant rate of pressure to the skin surface, with a corresponding number on the device indicating the pressure amount. Pressure was applied until the first sensation of pain was signaled by the participant, after which the algometer was immediately removed. Pressure pain threshold was defined as the amount of pressure in foot-pounds at which the participant first reported experiencing pain. Two trials were performed at each of two different body sites (4 trials total at each time point) during each time point: 1) on the anterior dominant arm eight centimeters down from the participants elbow crease and 2) dominant thigh at ten centimeters above the knee. Inter-trial-intervals were 20-seconds. The order of the PPT tests at each body site (forearm and thigh) was randomized and counterbalanced across participants to reduce an order effect. The PPT trials were completed 1) after resting measures (before game familiarization), 2) immediately before the 15-minute VR gameplay, and 3) immediately after the 15-minute VR gaming session while the participant was still wearing the VR headset. Pressure pain threshold testing is a reliable method of assessing pressure pain sensitivity in healthy, young adults (Aytar, Senbursa, Baltaci, Yuruk, & Pekyavas, 2014; Bisset, Evans, & Tuttle, 2015; Chesterton, Sim, Wright, & Foster, 2007; Waller, Straker, O'Sullivan, Sterling, & Smith, 2015). Percent change in PPT's was calculated from Pre-VR to Post-VR to evaluate the magnitude of hypoalgesic differences among the VR games. Percent change in PPT for the forearm and thigh for each game was calculated using the following method: ((Post-VR PPT -PreVR PPT)/(Pre-VR PPT)*100). The average value from the two trials for each site and each time point were used in statistical analysis.

Data Analysis

Power analysis. A power analysis was conducted using G Power 3.1.5 to determine an appropriate sample size. To adequately compare physical activity intensity variables (HR, RPE, enjoyment, accelerometry) between games, the power calculation (power = 0.80) revealed that thirty-six (36) participants were needed (See Table 3). This calculation was performed with alpha set at 0.05 and an estimated effect size of f=0.25. Furthermore, a power analysis also showed that the minimum sample size for detecting within-group differences with a moderate effect size (f=0.25) between the pre- and post-pain measures with an alpha level of 0.05 and power of 0.80 was sixteen (16) subjects.

Table 3. Power Analysis

Measure	A Priori
Effect Size (f)	.25 Medium
Alpha (α)	.05
Power (1-β)	.80
Sample size total (n)	36

Statistical Software and Analysis. SPSS was used for data analysis. Means and standard deviations for each variable for each condition was calculated. Descriptive statistics for demographic variables and IPAQ data were calculated.

To address the first hypothesis in Specific Aim 1, 2(sex) x 4(Game) mixed model ANOVAs with repeated measures on Game were conducted on the physical activity intensity measures (%HRR, RPE, hip, wrist, and thigh accelerometer variables). To address the second hypothesis of Specific Aim 1, values from the analysis were compared to metrics associated with moderate intensity activity to determine if moderate intensity activity was reached during gameplay: 1) %HRR between 40 and 59%, 2) RPE values between 12 and 13, and 3) accelerometry cut-points for wrist and hip between 1952 and 5724. For Specific Aim 2, 2(sex) x 4(Game) mixed model ANOVAs were conducted on the enjoyment variables (VAS, modified PACES). For Specific Aim 3, we first conducted a preliminary analysis to determine whether the PPT's significantly changed from the familiarization assessment to the pre-test using a 4(Game) x 2(Time: familiarization vs. pretest) x 2(sex) mixed model ANOVA. The results showed that PPT's did not significantly change from the familiarization trials to the pretest trials for the forearm PPT [$F(1, 34) = 0.010$, $p < 0.922$] and thigh PPT [$F(1, 34) = 1.762$, $p < 0.193$] trials. Therefore, primary focus on forearm and thigh PPT effects were evaluated between pre-VR and post-VR data. Thus, Specific Aim 3 was evaluated with 4(Game) x 2(Time: pretest vs. posttest) x 2(sex) mixed model ANOVAs. These analyses were conducted separately for the average PPT's on the forearm and thigh. Subsequently, the percent change in PPT's were evaluated with 4 (Game) x 2(Sex) mixed model ANOVAs. This analysis was used to determine the magnitude of hypoalgesic differences between games. Similarly, these analyses were conducted separately for the forearm and thigh. If the sphericity assumption was violated, then Greenhouse-Geisser degrees of freedom corrections was applied to obtain the critical p-value. Post-hoc analyses were conducted by using the Tukey HSD test. Statistical significance was determined at $p \leq 0.05$ for all analyses.

During data collection, some accelerometer data was lost due to accelerometer malfunctions (See Appendix B). These included wrist, waist, and thigh accelerometer variables for one subject during Holopoint, and one subject during Beat Saber. Lost data also included wrist accelerometer data for one subject during Holopoint, and thigh accelerometer data for one subject during Hot Squat.

CHAPTER 4

RESULTS

Participant Characteristics

Thirty-six (n=36) participants completed all sessions, with equal number of males (n=18) and females (n=18). Sample characteristics including age, body mass index (BMI), and IPAQ scores are in Table 4. The Shapiro-Wilk's test showed that IPAQ scores were not normally distributed and the Mann-Whitney U test showed that the IPAQ scores were not significantly different between males and females [$Z = -1.424$, $p < 0.161$]. Age was not significantly different between males and females [$t = 1.117$, $p < 0.272$)], while BMI was significantly different between males and females [$t = 2.489$, $p < 0.018$) with males having higher BMI's than females. Physical activity scores from the IPAQ were compared to the categories established by the IPAQ data processing method ("The International Physical Activity Questionnaire," 2005). The three levels of physical activities were 1) Low: < 600 MET*minutes/week, 2) Moderate: >600 MET*minutes/week, and 3) High: >3000 MET*minutes/week). Total IPAQ scores show that the study sample fell within the High physical activity category. All participants reported low to no experience with VR gaming.

Table 4. Descriptive statistics of sample (Means and SD)

	Male	Female
Age (years)	22.2 (2.8)	21.1 (3.1)
IPAQ (MET*minutes/week)	6188.92 (4938.06)	4140.11 (4399.48)
BMI (kg/m^2)	28.39	23.53

SD: Standard deviation; m: meter; kg: kilogram; IPAQ: International Physical Activity Questionnaire; BMI: Body Mass Index

Physical Activity Intensity Measures

Percentage of Heart Rate Reserve (%HRR)

The ANOVA showed a significant main effect of game on %HRR [F (2.14, 75.3) = 101.145, p < 0.001]. Follow-up analysis with Tukey HSD test showed that participants had significantly: 1) higher %HRR during Hot Squat than during Holopoint, Beat Saber, and Relax Walk VR, and 2) higher %HRR during Holopoint compared to Beat Saber and Relax Walk VR. No significant difference existed between Beat Saber and Relax Walk VR. Examining the %HRR descriptively, Hot Squat had values consistent with moderate intensity (40 –59% HRR), while all other games fell below light intensity (< 30% HRR). The ANOVA showed no main effect of sex [F (1, 34) = 0.874, p < 0.357] and no significant interaction between game and sex [F (2.214, 75.3, p < 0.061]. Means and standard deviations for %HRR for each game are in Table 5.

Table 5. Means and standard deviations (SD) for %HRR, average RPE, and maximal RPE for each VR game.

	Beat Saber	Holopoint	Hot Squat	Relax Walk VR
%HRR	13.5 (5.8)	28.0 (13.1)	41.3 (13.0)	8.0 (7.2)
Average RPE	9.5 (1.7)	11.4 (2.0)	13.4 (1.4)	6.7 (1.0)
Maximal RPE	10.9 (2.0)	13.1 (2.0)	15.5 (1.7)	7.1 (1.2)

%HRR: Percentage heart rate reserve; RPE: Ratings of perceived exertion

Ratings of Perceived Exertion (RPE)

Average RPE. The ANOVA showed a significant main effect of game on average RPE [F (3, 102) = 159.914, p < 0.001], with no significant main effect of sex [F (1, 34) = 1.259, p < 0.270] and no significant game by sex interaction [F (3, 102) = 1.160, p < 0.329]. Follow-up analysis on the main effect of game with Tukey HSD test showed that 1) the average RPE for Hot Squat was significantly higher than for all games, 2) average RPE for Holopoint was higher than Beat Saber and Relax Walk VR, and 3) average RPE for Beat Saber was significantly higher than for Relax Walk VR. Examining the data descriptively, average RPE values for Beat Saber and Hot Squat were consistent with moderate intensity (12 -13 RPE), while Holopoint fell within the upper range of light intensity (9 – 11 RPE) and Relax Walk VR fell near little-to-no exertion at all (6 RPE).

Maximum RPE. Similarly, the ANOVA showed a significant main effect of game on maximal RPE [F (3, 102) = 208.693, p < 0.001], with no significant main effect of sex [F (1, 34) = 2.181, p < 0.149] and no significant game by sex interaction [F (3, 102) = 1.284, p < 0.284]. Follow-up Tukey HSD tests for the main effect of game showed that maximal RPE for Hot Squat was significantly higher than the maximal RPE values for

Holopoint, Beat Saber, and Relax Walk VR. Additionally, max RPE during Holopoint was significantly higher than during Beat Saber and Relax Walk VR, and RPE during Beat Saber was significantly higher than Relax Walk VR. Means and standard deviations for average and maximal RPE values are in Table 5.

Accelerometer Variables

Physical activity of the dominant upper limb (arm accelerometer)

Percentage of time in sedentary time. The ANOVA showed a main effect for both game [$F(2.016, 62.501) = 573.284$, $p < 0.001$] and sex [$F(1, 31) = 6.032$, $p < 0.020$] on percentage of sedentary time for arm accelerometry. Both effects were superseded by a game by sex interaction [$F(2.016, 62.501) = 3.860$, $p < 0.026$]. The Tukey HSD test showed that percentage of time in arm sedentary activity for males and females in Beat Saber and Holopoint were significantly lower than percentage of arm sedentary time for males and females in Hot Squat and Relax Walk VR. Male and female participants spent significantly more time in arm sedentary activity while playing Relax Walk VR than playing Hot Squat. Means and standard deviations for percentage of time in arm sedentary activity by game and sex are presented in Table 6a.

Percentage of time spent in light activity. The ANOVA showed a significant main effect of game [$F(3, 78.649) = 59.801$, $p < 0.001$] and sex [$F(1, 31) = 4.769$, $p < 0.037$]. These effects were superseded by a significant interaction between game and sex [$F(3, 93) = 3.627$, $p < 0.016$]. The Tukey HSD test showed multiple significant comparisons. For both males and females, the percentage of time spent in light arm activity for Hot Squat was significantly higher than percentage of time in arm light activity for Beat Saber, Holopoint, and Relax Walk VR. Also, females spent significantly more time in arm light activity during Holopoint than males during Holopoint. Both males and females spent significantly more time in arm light activity during Beat Saber than during Relax Walk VR. Means and standard deviations for percentage of time spent in arm light activity by game and sex are presented in Table 6a.

Percentage of time spent in MVPA. The ANOVA showed a significant main effect of game [F (3, 93) = 235.315, p < 0.001] and sex [F (1, 31) = 12.654, p < 0.001], with no significant interaction between game and sex [F (3, 93) = 189.854, p < 0.106]. Males (57.20% + 8.41%) spent more time in arm MVPA during gameplay than females (46.79% + 8.41). For the main effect of game, participants spent more time in arm MVPA during Holopoint (84.17% + 14.45) and Beat Saber (77.19% + 14.47) than during Hot Squat (42.66% + 19.09) and Relax Walk VR (3.96% + 8.40). Also, time spent in arm MVPA activity was significantly higher during Hot Squat than during Relax Walk VR. Means and standard deviations for percentage of time spent in arm MVPA by game and sex are in Table 6a.

Whole body physical activity (waist accelerometer)

Percentage of time in sedentary time. The ANOVA showed a significant main effect of game [F (1.818, 58.173) = 144.379, p < 0.001] and sex [F (1, 32) = 12.366, p < 0.001) for whole-body sedentary activity. These effects were superseded by a significant interaction between game and sex [F (1.818, 58.173) = 11.434, p < 0.001]. Tukey HSD follow-up tests showed that females spent more time in sedentary activity during Holopoint than males. The test also showed that both males and females spent significantly less time in sedentary activity during Holopoint and Hot Squat than during

Beat Saber and Relax Walk VR. Means and standard deviations for whole-body sedentary time by game and sex is in Table 6b.

Percentage of time spent in light activity. The ANOVA showed a significant main effect of game [F (3, 96) = 67.672, p < 0.001] and no main effect of sex [F (1, 32) = 1.399, p < 0.246]. The game effect was superseded by a game by sex interaction [F (3, 96) = 15.052, p < 0.001]. Tukey HSD test showed that males spent greater time in light activity during Holopoint than during Beat Saber, Hot Squat, and Relax Walk VR. Females spent more time in whole-body light activity during Hot Squat than during Holopoint, Beat Saber, and Relax Walk VR. Males significantly spent more time in whole-body light activity during Holopoint than females while playing Holopoint and Hot Squat. Across males and females, time spent in whole-body light activity was significantly higher during Beat Saber, Holopoint, and Hot Squat when compared to Relax Walk VR. Means and standard deviations for time in whole-body light activity by game and sex is presented in Table 6b.

Percentage of time spent in MVPA. The ANOVA showed a significant main effect of game [F (1.661, 53.148) = 56.721, p < 0.001] and sex [F (1, 32) = 164.605, p < 0.004] on time in whole-body MVPA. The game by sex interaction was not statistically significant but approached significance [F (1.661, 53.148) = 3.359, p < 0.051]. Males spent more time in whole-body MVPA during gameplay than females (males = 16.45% + 8.52%, females 10.05% + 8.52%). Tukey HSD test showed that time spent in whole-body MVPA for Hot Squat (34.84% + 19.51%) was significantly higher than whole-body activity during Beat Saber (2.14% + 2.10%), Holopoint (15.35% + 16.68%), and Relax Walk VR (0.19% + 0.65%). Whole-body MVPA during Holopoint was significantly higher than during Beat Saber and Relax Walk VR. Means and standard deviations for percentage of time in whole-body MVPA by game and sex is in Table 6b.

Physical activity of the ipsilateral lower limb (thigh accelerometer)

Percentage of time in sedentary time. The ANOVA showed a main effect of game [F (2.062, 65.928) = 146.849, p < 0.001] and sex [F (1, 32) = 14.541, p < 0.001] for lower body sedentary activity. These effects were superseded by a game by sex interaction [F (2.062, 65.982), p < 0.001]. Follow-up Tukey HSD tests showed that both males and females significantly spent less time in lower body sedentary activity during Holopoint and Hot Squat than while playing Beat Saber and Relax Walk VR. Females spent more time in lower body sedentary activity during Holopoint than during Hot Squat gameplay. Additionally, males spent less time in lower body sedentary activity during Holopoint than females during Holopoint gameplay. Means and standard deviations for percentage of time in lower body sedentary activity by game and sex is presented in Table 6c.

Percentage of time spent in light activity. The ANOVA showed a significant main effect for game [F (2.440, 78.068) = 99.033, p < 0.001] and no effect of sex [F (1, 32) = 0.100, p < 0.754] on lower body light activity. The game effect was superseded by a game by sex interaction [F (2.440, 78.068), p < 0. 031]. Follow-up Tukey HSD showed that males and females spent more time in lower body light activity during Holopoint and Hot Squat gameplay than during Beat Saber and Relax Walk VR gameplay. Males spent significantly more time in lower body light activity during Holopoint than Hot Squat. Means and standard deviations for lower body light activity by game and sex are presented in Table 6c.

Percentage of time spent in MVPA. The ANOVA showed a significant main effect of game [F (1.754, 56.132) = 38.666, p < 0.001] and sex [F (1, 32) = 21.130, p < 0.001] on lower body MVPA. These effects were superseded by a game by sex interaction [F (1.754, 56.132) = 6.938, p < 0.001]. Follow-up Tukey HSD tests showed males spent more time in lower body MVPA during Hot Squat and Holopoint than during Beat Saber and Relax Walk VR. Further follow-up tests showed that females spent more time in lower body MVPA during Hot Squat than during Beat Saber, Holopoint, and Relax Walk VR. The Tukey HSD test also showed that males spent more time in lower body MVPA during Hot Squat than females during Hot Squat. Males also spent more time in lower body MVPA during Holopoint than females during Holopoint. Means and standard deviations for percentage of time spent in lower body MVPA by game and sex is presented in Table 6c.

Table 6a. Means and standard deviations (SD) for upper limb (wrist) accelerometer variables (% of time spent in activity) for each game by sex and body site.

	Beat Saber		Holopoint		Hot Squat		Relax Walk VR	
	Males	Female	Male	Female	Male	Female	Male	Female
Physical activity of dominant upper limb (Wrist accelerometer)								
Sedentary	5.81	7.30	0.83	2.40	19.53	32.88	91.33	93.32
	(3.06)	(4.24)	(0.67)	(2.46)	(9.38)	(2.46)	(17.01)	(11.71)
Light	12.43	14.57	6.49	16.92	30.73	28.57	4.51	3.33
	(6.33)	(7.91)	(6.19)	(7.28)	(9.85)	(8.64)	(8.57)	(5.67)
MVPA	81.76	74.61	92.68	75.97	49.72	37.93	4.33	3.35
	(9.08)	(18.33)	(6.74)	(19.57)	(15.94)	(21.88)	(9.46)	(6.31)

MVPA: Moderate-to-vigorous physical activity, VR: Virtual Reality

Table 6b. Means and standard deviations (SD) for whole body (waist) accelerometer variables (% of time spent in activity) for each game by sex and body site.

	Beat Saber		**Holopoint**		**Hot Squat**		**Relax Walk VR**	
	Males	Female	Male	Female	Male	Female	Male	Female
Whole body physical activity (Waist accelerometer)								
Sedentary	87.89	84.80	34.54	69.79	31.56	36.42	98.29	99.52
	(12.67)	(11.40)	(20.12)	(24.65)	(12.09)	(16.25)	(6.54)	(1.07)
Light	10.45	12.61	44.42	20.87	24.68	35.17	1.52	0.30
	(11.75)	(9.44)	(10.10.65)	(16.10)	(11.62)	(15.14)	(5.79)	(0.63)
MVPA	1.66	2.60	21.03	9.34	41.68	28.01	0.19	0.19
	(1.33)	(2.59)	(19.55)	(10.49)	(18.66)	(18.34)	(0.75)	(0.54)

MVPA: Moderate-to-vigorous physical activity, VR: Virtual Reality

Table 6c. Means and standard deviations (SD) for lower limb (thigh) accelerometer variables (% of time spent in activity) for each game by sex and body site.

	Beat Saber		**Holopoint**		**Hot Squat**		**Relax Walk VR**	
	Males	Female	Male	Female	Male	Female	Male	Female
Physical activity of ipsilateral lower limb (Thigh accelerometer)								
Sedentary	89.69	89.25	31.53	61.89	35.86	45.85	98.52	99.40
	(11.79)	(7.98)	(24.71)	(17.70)	(16.12)	(15.28)	(6.06)	(0.99)
Light	9.10	9.50	43.11	33.72	27.71	35.26	1.27	0.33
	(7.20)	(7.20)	(14.03)	(14.80)	(10.11)	(15.17)	(5.21)	(0.46)
MVPA	1.21	1.25	25.42	4.41	35.77	18.90	0.21	0.27
	(1.52)	(1.06)	(22.41)	(4.14)	(18.53)	(15.17)	(0.84)	(0.68)

MVPA: Moderate-to-vigorous physical activity, VR: Virtual Reality

Enjoyment Variables

Visual Analog Scale (VAS). The ANOVA showed a significant main effect of game on VAS scores [F (2.535, 86.204) = 37.100, p < 0.001] with no significant effect of sex [F (1, 34) = 0.039, p < 0.844] and no significant game by sex interaction [F (2.535, 86.204), p < 0.116]. Follow-up Tukey HSD test showed that Beat Saber and Holopoint were rated significantly more enjoyable than Hot Squat and Relax Walk VR. The results indicated no significant differences in VAS scores between Beat Saber and Holopoint, and no differences between Hot Squat and Relax Walk VR. Means and standard deviations for VAS scores by game are presented in Table 7.

Physical Activity Enjoyment Scale (PACES). Similarly, the ANOVA showed a significant main effect of game on PACES score [F (3, 102) = 34.219, p < 0.001] with no significant main effect of sex [F (1, 34) = 0.414, p < 0.524] and no significant game by sex interaction [F (3, 102) = 0.842, p < 0.474]. Follow-up Tukey HSD tests showed that Beat Saber and Holopoint were more enjoyable than Hot Squat and Relax Walk VR. No significant differences existed between Beat Saber and Holopoint, and no difference existed between Hot Squat and Relax Walk VR. Means and standard deviations for PACES scores by game are presented in Table 7.

Table 7. Means and standard deviations (SD) for VAS and PACES (%) scores by game.

	Beat Saber	Holopoint	Hot Squat	Relax Walk VR
VAS	8.0 (1.7)	7.6 (1.9)	4.5 (2.5)	4.2 (2.5)
PACES (%)	90.9 (8.9)	84.5 (14.0)	65.4 (18.5)	69.4 (14.5)

VAS: Visual Analog Scale (cm); PACES: Physical Activity Enjoyment Scale

Pain Sensitivity

Pressure Pain Thresholds (PPT's). The ANOVA conducted on forearm PPT's showed a main effect of time [F (1, 34) = 9.373, p < 0.004], with a significant increase from Pre-VR PPT's (9.16 + 7.01 lb*ft) to Post-VR PPT's (9.72 + 7.48 lb * ft). The ANOVA for the forearm PPT's also showed a main effect of sex [F (1, 34) 5.735, p < 0.022) and a game by sex interaction [F (3, 34) = 3.310, p < 0.023]. All other effects and interactions including game [F (3, 34) = 1.330, p < 0.269], time by sex [F (1, 34) = 0.853, p < 0.362), game by time [F (3, 102) = 0.258, p < 0.855), and game by time by sex [F (3, 102) = 0.904, p < 0.442) were not statistically significant. The ANOVA conducted on thigh PPTs also showed a main effect of time (p < 0.001). This main effect was superseded by a game by time interaction (p < 0.010). Follow-up Tukey HSD tests showed that thigh PPT values significantly increased from pre-VR to post-VR for Holopoint, Hot Squat, and Relax Walk VR, but not for Beat Saber. Means and standard deviations for PPT's for each game by time and body site are located in Table 8.

Percent change in PPT's. To determine whether differences existed in the magnitude of hypoalgesia between games, the percent change in PPT's for the forearm and thigh were evaluated. The ANOVA revealed no main effects for game [F (3, 102) = 1.055, p < 0.372) and sex [F (1, 34) = 0.021, p < 0.886), and no significant game by sex interaction [F (3, 102) = 1.163, p < 0.328) on percent change in forearm PPT's. For the thigh PPT's, the ANOVA showed a main effect of game [F (3, 102) = 3.771, p < 0.013), no effect of sex [F (1, 34) = 0.113, p < 0.739) and no game by sex interaction [F (3, 102) = 0.832, p < 0.479). Follow-up Tukey HSD tests on the main effect of game showed that percent change in PPT's was significantly higher for Hot Squat than for Beat Saber and

Relax Walk VR. No other differences in percent change in PPT's among the VR games was found. Means and standard deviations for percent change in PPT's for each game by body site is located in Table 9.

Table 8. Means and standard deviations (SD) for Pressure Pain Thresholds across Game, Time, and Body Site.

	Beat Saber	**Holopoint**	**Hot Squat**	**Relax Walk VR**
Thigh				
Familiarization	13.0 (8.1)	12.6 (8.1)	14.0 (10.1)	13.3 (9.1)
Pre-VR	13.5 (9.7)	12.6 (8.8)	14.2 (9.4)	13.5 (9.7)
Post-VR	14.1 (9.8)	14.2 (10.3)	16.3 (10.7)	14.7 (11.4)
Forearm				
Familiarization	9.2 (8.3)	8.7 (7.9)	9.2 (6.8)	9.6 (8.7)
Pre-VR	9.5 (8.5)	8.6 (7.1)	9.2 (7.5)	9.5 (7.7)
Post-VR	10.0 (8.7)	9.2 (7.9)	9.9 (7.2)	9.8 (9.0)

Note: VR: Virtual Reality; Pain Pressure Threshold units: lb*ft

Table 9. Means and standard deviations (SD) for Percentage Change in Pressure Pain Thresholds from Pre-VR to Post-VR across Game and Body Site.

	Beat Saber	Holopoint	Hot Squat	Relax Walk VR
Forearm	4.78 (20.39)	8.56 (16.08)	9.14 (21.67)	2.51 (15.12)
Thigh	6.08 (15.79)	12.01 (18.35)	16.23 (17.63)	6.63 (13.47)

Note: VR: Virtual Reality

CHAPTER 5

DISCUSSION

The purpose of this study was to evaluate the effect of commercial VR gaming technology on physical activity intensity levels, enjoyment, and pain sensitivity in young healthy adults. Results from this study revealed several key findings. First, participants reached higher physical activity intensity levels while playing the active VR games compared to the non-active VR game, with game intensities ranging from light to moderate depending on the game and intensity measure. Second, enjoyment was greatest for the VR games that required the most arm movement and elicited an overall light intensity and exertion via RPE and %HRR. Enjoyment was lower for the game eliciting little movement and no exertion and the game eliciting the highest exertion and whole-body intensity. Lastly, playing VR games elicited a temporary hypoalgesic effect following the 15-minute bouts of gameplay, with this effect enhanced in the VR game eliciting the greatest physical activity intensity.

Physical Activity During Virtual Reality Gameplay

Over the past two decades, a large body of research has evaluated physical activity levels during active video games played on systems such as the Nintendo Wii and Xbox Kinect (K. E. Naugle & Wikstrom, 2014; Peng et al., 2013). Generally, this research has shown that active video games elicit light to moderate physical activity, while being perceived as enjoyable. Virtual reality is the latest iteration of gaming technology that allows users to be physically active while achieving video game objectives. Researchers have hypothesized that VR could offer an advantage over prior active gaming systems because it could provide greater levels of immersion that allow participants to reach higher intensity levels while perceiving lower exertion during gameplay (Gomez et al., 2018). However, very little research has examined active VR games, with the current study the first to evaluate physical activity levels in Beat Saber, Hot Squat, and Relax Walk VR.

Based on the prior active gaming literature, it was hypothesized that active VR games would yield higher physical activity intensity levels than non-active VR games and that active VR games would allow participants to reach moderate intensity activity as defined by objective (i.e., %HRR, accelerometry) and subjective (RPE) metrics. The results partially supported this hypothesis. First, the %HRR data indicated that Hot Squat and Holopoint elicited greater physical activity intensity than the non-active VR game Relax Walk; however, Beat Saber did not. Also based on the %HRR values, gameplay during Hot Squat reached on average moderate intensity (40 – 59% HRR), while gameplay during the other VR games (Beat Saber, Holopoint, and Relax Walk VR) fell below light intensity activity for the fifteen-minutes of gameplay. Similarly, the RPE results indicated that participants perceived Hot Squat as moderate to vigorous intensity, with Holopoint and Beat Saber rated as light intensity, and Relax Walk VR perceived to be little-to-no exertion. Maximal RPE for Holopoint did reach moderate intensity.

Taking the results together, each game in the current study had similar intensity categorizations based on RPE and %HRR. This is in contrast to Gomez et al who found that active VR games (Thrill of the Fight, Audioshield, and Holopoint) had higher physical activity intensity categorizations via objective measures (METS and %VO2R) compared to subjective measures (RPE) (Gomez et al., 2018). For example, Holopoint fell within moderate intensity as defined METS, but was rated as light intensity via RPE.

The authors suggested that VR may provide sufficient distraction to cause lower perceived effort during gameplay while maintaining higher intensity levels. However, further research is needed to test this hypothesis, as these results do not support this assertion. It is possible that intensity levels need to be higher during game play than in the current study for the objective vs subjective discrepancies in intensity to emerge.

Also, in contrast to Gomez et al., Holopoint in the present study elicited a light rather than moderate intensity (Gomez et al., 2018). Several methodological differences between the two studies could account for the discrepant result. First, %HRR and RPE were measured across the total fifteen-minute gameplay period, while Gomez et al. only analyzed minutes four to eight out of the total ten-minute period. Thus, the Gomez data likely represented more steady state activity during gameplay, whereas the current data likely included more of the intermittent pauses and breaks inherent in these games. Second, Gomez et al implemented a custom setting for the games which provided a challenging difficulty level for the participants. In the current study, participants played each game on either a normal difficulty setting or started on the lowest intensity setting and progressed during gameplay. Beat Saber included difficulty levels ranging from "Easy" to "Expert+" and participants played on "Normal" difficulty. Hot Squat did not have any custom settings for difficulty. Hot Squat progressively increased intensity by starting with fewer and slow-paced squats and gradually increased squatting frequency and reduced the duration between each squat. Holopoint included difficulty levels ranging from "2" to "5" and included optional targets such as rectangular cubes and holographic human targets. Participants played at level "2" difficulty and only targeted the rectangular cubes.

The accelerometer data collected in this study also provided valuable information regarding the type and intensity of movements elicited by each game. Across the whole sample, participants demonstrated higher levels of whole-body and lower body sedentary behavior during Beat Saber and Relax Walk VR compared to Holopoint and Hot Squat. For example, over 80% of the gameplay period was spent in whole-body and lower body sedentary time during Beat Saber, whereas only approximately 30-45% of time was spent in whole-body sedentary behavior during Hot Squat. Furthermore, time in whole-body MVPA was highest during Hot Squat gameplay, followed by Holopoint, with very little whole-body MVPA during Beat Saber and Relax Walk VR. The lack of time spent in whole and lower-body activity for Beat Saber is likely because this game is primarily an upper body-based game where little lower body movement is needed to play the game successfully. In line with this notion, the data revealed the highest levels of moderate to vigorous arm movement during Beat Saber and Holopoint, with approximately 75 to 85% of gameplay spent in arm MVPA. However, prior active gaming research has shown that lower and whole-body movement compared to upper-limb movement is more important to reaching energy expenditure levels consistent with MVPA (M. Duncan & Dick, 2012; Jordan et al., 2011; Scheer et al., 2014).

Another interesting and important finding from the accelerometer data was in regard to how males and females play these games differently. Most prior gaming studies have not examined sex difference in how active games, including VR games, are played. One key finding was that males had greater amounts of MVPA while playing active VR games compared to females regardless of accelerometer location. These sex differences were particularly magnified during Holopoint and Hot Squat. For example, males spent more lower body MVPA during Hot Squat (~36% vs. 19%) and Holopoint (~25% vs. 4%) than females did during those same games. Additionally, females spent approximately 60-70% of gameplay in whole-body and lower limb sedentary time during Holopoint, whereas males only spent 30-35% of gameplay in whole and lower body sedentary time during this game. While one can only speculate on what caused the sex differences in VR gameplay, prior research suggests that males are relatively more competitive, aggressive, and goal-oriented in sports-based activities than females (Deaner, Balish, & Lombardo, 2016). Thus, these potential sex-related differences in competitive based activities along with the self-selected intensity instructions for gameplay could explain the movement differences between males and females; however, future research needs to test this hypothesis.

In summary, the present study demonstrated that Hot Squat was able to consistently elicit moderate intensity activity. Holopoint and Beat Saber fell within light intensity and Relax Walk VR elicited nearly no physical activity. Given that games in the current study were played at a self-selected intensity and at a lower/beginner setting, the results likely represent the lower threshold of physical activity that individuals would reach while playing these games. Notably, prior active gaming research suggests that physical activity intensities within a game can vary significantly based on several factors including game instructions, level, and number of players etc (Bosch et al., 2012; Kraft et al., 2011; O'Donovan & Hussey, 2012; Sell et al., 2008).

Enjoyment during Virtual Reality Gameplay

Broadly speaking, acute emotional responses to physical activity or bouts of exercise can be predictors of future physical activity participation (Williams, 2008). More specifically, past research suggests high enjoyment of physical activity could lead to regular adherence (P. Ekkekakis et al., 2011). Thus, a second purpose of this study was to determine which VR games elicited higher enjoyment levels in young, healthy adults. We hypothesized that VR games requiring more body movement would elicit higher enjoyment levels than games requiring less body movement. Data from Visual Analog Scale (VAS) and the modified Physical Activity Enjoyment Scale (PACES) only partially supported the hypothesis. Beat Saber and Holopoint were rated more enjoyable than Relax Walk VR and Hot Squat. Interestingly, the two games rated lowest in enjoyment required the most (Hot Squat) and least (Relax Walk) intense effort and physical activity, while the games rated highest in enjoyment required mostly arm movement and a perceived light exertion. Even though sex differences were found in the type and intensity of movement during gameplay, no differences existed between males and females in reported enjoyment of the VR games.

Few studies have evaluated enjoyment of active VR games. In one of the few studies doing so, Gomez et al. asked participants to rank which active VR games were most enjoyable following gameplay. Holopoint was ranked the most enjoyable, followed by Audioshield and Thrill of the Fight (Gomez et al., 2018). Similarly, the data revealed high enjoyment levels for Holopoint. In a study conducted by Yoo and colleagues, which included no formal assessment of enjoyment, participants were able to choose the amount of time each VR game was played (between 2 and 10 minutes) (Yoo et al., 2017). Participants played Hot Squat for the least amount of time (~6 minutes) while the other games (Holopoint, Fruit Ninja, and Portal Stories) were played the maximal time allowed. While Hot Squat is not a traditional form of physical activity, participants are required to make repetitive and rapid squatting movements for the majority of game play. Prior research suggests that repetitive or monotonous activities, like walking or running, may be perceived as boring and could lead to less physical activity participation (Geiwitz, 1966). As such, the monotonous or repetitive movements of Hot Squat may have led to the lower enjoyment ratings. Conversely, engaging in the 360-degree environment of Holopoint while constantly looking for targets to shoot and the anticipation of incoming cubes to hit while listening to upbeat music during Beat Saber likely elicited movements that were not considered monotonous or repetitive, potentially contributing to higher enjoyment levels. Overall, results from the current and prior studies suggest that healthy young adults experience greater relative enjoyment during active VR games which require significant movement and immersion, but not necessarily intense physical effort.

The Hypoalgesic effects of the Virtual Reality Games

The third purpose of the study was to assess whether playing VR games would have an acute hypoalgesic effect on experimentally induced pain in young, healthy adults. Based on prior literature, the first hypothesis was that playing VR games would acutely decrease pressure pain sensitivity following each gaming session. The results supported this hypothesis as participants experienced an overall hypoalgesic effect in the forearm and thigh following fifteen-minute bouts of VR gaming. Notably, the magnitude of the hypoalgesic effect on the forearm did not differ between VR games. Previous VR research has primarily focused on VR games or experiences that involve little to no physical activity. The research indicates that passively engaging in VR while seated or standing has a positive impact on pain sensitivity (Boylan et al., 2018; Magora et al., 2006). The primary mechanism attributed to these effects involve distraction. This distraction theory suggests that while focus is given to stimuli other than pain, the pain stimulus would not be perceived as painful. This is based on the understanding that sensory systems have limited capacity in focusing on multiple external stimuli simultaneously; therefore, the external stimuli would draw the attention of the individual from the pain stimulus (H. G. Hoffman et al., 2007; McCaul & Malott, 1984). The PPT data during Relax Walk VR from the current study particularly supports the prior literature showing that passive VR games and experiences could be used as a distraction tool for pain (H. G. Hoffman et al., 2007; Magora et al., 2006).

Subsequently, it was also hypothesized that playing VR games which required relatively more physical activity or movement (Beat Saber, Holopoint, and Hot Squat) would have a greater hypoalgesic effect than the non-active VR game (Relax Walk VR). Prior research shows that bouts of moderate-intensity physical activity and passive VR separately induce hypoalgesic effects (Glennon et al., 2018; Jin et al., 2016; K. M. Naugle et al., 2012). However, whether these hypoalgesic effects could be enhanced by combining the two methods (i.e., VR that incorporates physical activity) has received little attention. Importantly, the data provide strong and novel evidence for an enhanced hypoaglesic effect when combining moderate-intensity whole-body movements and VR distraction compared to VR distraction alone. Specifically, the magnitude of pain reduction at the thigh was greatest for the game eliciting the greatest cardiovascular response, as well as the greatest amount of whole and lower body MVPA (i.e., Hot Squat). Indeed, the magnitude of pain reduction following Hot Squat was over twice as high as the game requiring minimal movement (Relax Walk VR) and the game categorized as less than light intensity with little whole-body movement (Beat Saber).

This is in accordance with prior active gaming research showing that a primary factor determining whether an active game elicits exercise-induced hypoalgesia is the intensity level reached during game play. (Carey et al., 2017; K. E. Naugle et al., 2017).

Prior research had provided preliminary evidence that hypoalgesia could be enhanced when the distraction effects of VR are combined with movement. For example, Czub, et al. evaluated how different levels of arm movement using scaled computer mouse movements during VR gameplay affected cold pain sensitivity in healthy adults. The authors found that larger arm movements elicited lower pain intensities during cold water immersion than smaller arm movements, suggesting that more movement may be associated with positive pain outcomes in VR tasks (Czub & Piskorz, 2017). Another study compared the hypoalgesic effects of VR combined with exercise imagery to VR distraction (Hayashi et al., 2019). The results revealed that VR combined with exercise imagery resulted in higher pressure pain thresholds during the VR task compared to VR without exercise imagery. However, the current study is the first to examine the impact of VR experiences that include actual light to moderate intensity whole body movements on pain sensitivity.

Contrary to expectations, an additive effect of VR and physical activity was found only when measuring PPT's of the thigh vs. the forearm, although the forearm data trended in the hypothesized direction. Several explanations could account for the differing results observed on these two body parts. First, exercise-induced hypoalgesia can be produced by both local and central pain inhibitory effects and these effects may be stronger when both effects are combined. Local effects are characterized by reductions in pain in the active or exercising limb. Central effects are characterized by pain reductions in body parts distant to the exercising muscle (Gomolka et al., 2019). If the physical activity during VR gameplay induced central pain inhibitory effects, it would have expected a greater magnitude of pain reduction following Hot Squat compared to the other games at both the thigh and forearm. Central pain inhibitory effects following aerobic exercise usually requires the exercise to be at least moderate to vigorous intensity (Micalos & Arendt-Nielsen, 2016; K. M. Naugle et al., 2012; Vaegter et al., 2018), with greater effects evident at higher intensities. Thus, the active VR games possibly did not elicit intense enough physical activity or cardiovascular response to produce a central pain inhibitory response above and beyond that of the VR distraction. Further, the game eliciting the greatest cardiovascular response and requiring the most moderate to vigorous movement of the leg, Hot Squat, produced the greatest hypoalgesic effect on the leg compared to the other games. Thus, Hot Squat may have induced a stronger pain inhibitory effect on the thigh by combining both local and central mechanisms. These mechanisms could include changes in attention, changes in ß-endorphins, changes in plasma adrenaline and noradrenalin, peripheral nociceptive inhibition, and expressed endogenous opioid substances located both centrally and locally during and after exercise (Kosek & Lundberg, 2003; Micalos & Arendt-Nielsen, 2016; K. M. Naugle et al., 2012; Tegeder et al., 2003; Vaegter et al., 2014).

Limitations and Future Directions

Several limitations within this study need to be addressed. First, VR is a new technology and several VR games currently exist that were not examined in this study. Therefore, conclusions drawn can only be applied to the games examined within this study. Future VR research should focus on evaluating physical activity during other VR games and similar VR technologies that are commercially available. Second, the study sample included only healthy younger adults that reported high levels of physical activity; therefore, the results may not generalize to other populations. Future research should evaluate whether active VR games could have similar effects in different populations, including but not limited to older adults, sedentary individuals, and those with chronic and acute pain conditions.

Third, nearly all participants in the present study indicated little-to-no experience with VR gaming. Importantly, prior gaming experience may influence the intensity at which individuals engage in physical activity during active gaming. Previous literature shows that inexperienced players play at lower intensities when compared to more experienced players due to limited exposure to gaming technologies (Kraft et al., 2011; K. E. Naugle et al., 2014; Sell et al., 2008). However, other literature suggests that those with more experience with gaming technology may be more proficient at active games, thereby reducing the amount of physical effort required to successfully play (O'Donovan & Hussey, 2012). Even with the game familiarization component of the current study, participants may not have reached higher intensities due to lack of game proficiency or game familiarity. Future studies need to evaluate how VR gaming experience impacts physical activity intensity levels and enjoyment during games.

Fourth, the difficulty setting for the VR games was set on a normal difficultly level. It is unknown whether playing at higher difficulty levels would elicit higher intensities, enjoyment, and hypoalgesic effects. Most VR games have different difficulty settings where if participants play VR games regularly, difficulty can be adjusted to meet the player’s experience. As noted earlier, Gomez et al. used a custom difficulty setting to promote challenging VR gameplay and found that participants played at higher intensities than observed in the current study (Gomez et al., 2018). Future research should evaluate whether adjusting difficulty settings can elicit higher activity levels.

Finally, pressure pain thresholds were used as the mode to evaluate pain sensitivity. Other methods are available to use for pain assessment, such as heat tolerance via thermodes and cold-water immersion. Pressure pain testing was chosen in the current study because it utilized a portable pressure algometer, which made pain sensitivity testing more feasible to perform. Prior research has shown that hypoalgesic responses to exercise is partially a function of the experimental pain test (Naugle, Naugle, Fillingim, & Riley, 2013); thus, results with other methods of experimentally induced pain may be different. In addition, the study design did not include an exercise only condition. Thus, it is not known whether active VR induces an enhanced hypoalgesic effect compared to physical activity alone.

Summary

In summary, Hot Squat was the only active VR game that consistently elicited moderate intensity activity. However, all active VR games elicited more intense activity than the non-active VR game (Relax Walk VR). Hot Squat was perceived to be less enjoyable than Beat Saber and Holopoint, potentially due to the repetitive and monotonous squatting activity. As VR technology becomes more popular and accessible to the general population, future VR research should provide a foundational basis for including active VR gaming as a mode for obtaining regular physical activity in different populations.

This study also added to the body of evidence demonstrating that VR elicits hypoalgesic effects, and showed for the first time a potential additive effect of VR and whole-body physical activity on pain sensitivity. Collectively, the results suggest that both passive and active VR should be explored as an alternative mode for pain management. Furthermore, deconditioned or sedentary individuals could still benefit from the hypoalgesic effects of passive VR engagement, as seen with Relax Walk VR. Moreover, future research should explore active VR gaming as a viable exercise option for those with pain conditions. Given the interactive nature of active VR games, these games could possibly serve as a pleasant distraction from pain symptoms in individuals with chronic pain and thereby enhance compliance with exercise therapy. However, future research needs to test this hypothesis.

APPENDICES

APPENDIX A

QUESTIONNAIRES

Demographic and Screen Questionnaire

Subject #: _________ **Date:** ___ / ___ / ___

Instructions (may be administered verbally)

The following questions are designed to help us learn more about you and your eligibility for this study. Think about heat question carefully before you answer.

How old are you? _________ **years (AGE)**

Height: ______________(inches/centimeters)

Weight: _______________ (pounds/kilograms)

Are you left or right-handed? HANDED (Check one)

☐ 1- Left ☐ 2- Right

What is your race? (May choose more than one) **(RACE)**

☐	1 - African American	☐	3 - Caucasian	☐	5 - Native American
☐	2 - Asian/Pacific Islander	☐	4 - Hispanic	☐	6 - Other: ___________

What is your sex?

☐ 1 - Male ☐ 2 - Female

Have you ever experienced or are currently prone to motion sickness or claustrophobia?

☐ No ☐ Yes *Rule out*

Do you current experience any acute pain?

☐ No ☐ Yes *Rule out*

Do you currently experience any chronic pain?

☐ No ☐ Yes *Rule out*

Do you have any experience playing VR games?

0 – Never
1 – Equal to or less than 1 time per week
2 – 2 to 4 times per week
3 – 5 or more times per week

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (IPAQ)

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** 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. Think *only* about 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, digging, aerobics, or fast bicycling?

____________ **days per week**

No vigorous physical activities ☐ → ***Skip to question 3***

How much time did you usually spend doing **vigorous** physical activities on one of those days?

____________ **hours per day**

____________ **minutes per day**

Don't know/Not sure ☐

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about 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, bicycling at a regular pace, or doubles tennis? Do not include walking.

____________ **days per week**

No moderate physical activities ☐ → ***Skip to question***

How much time did you usually spend doing **moderate** physical activities on one of those days?

____________ **hours per day**

____________ **minutes per day**

Don't know/Not sure ☐

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

____________ **days per week**

No walking ☐ → ***Skip to question 7***

How much time did you usually spend **walking** on one of those days?

____________ **hours per day**

____________ **minutes per day**

Don't know/Not sure ☐

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent 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.

During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

____________ **hours per day**

____________ **minutes per day**

Don't know/Not sure ☐

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

Visual Analog Scale (VAS)

Enjoyment

Least enjoyable Most enjoyment possible

Modified Physical Activity Enjoyment Scale (PACES)

PACES items: Please rate how you feel *at the moment* about the physical activity you have been doing

1	2	3	4	5	6	7
* I enjoy it						I hate it
1	2	3	4	5	6	7
I dislike it						I like it
1	2	3	4	5	6	7
It's no fun at all						It's a lot of fun
1	2	3	4	5	6	7
* I feel good physically while doing it						I feel bad physically while doing it
1	2	3	4	5	6	7
I am very frustrated by it						I am not at all frustrated by it

* Item is reverse scored (ie, 1 = 7, 2 = 6, 3 = 5, 4 = 4, 5 = 3, 6 = 2, 7 = 1).

Physical Activity Readiness Questionnaire (PAR-Q)

2019 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ____________	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ____________	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it **does not limit your current ability** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ____________	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION
If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ______________________ DATE ______________

SIGNATURE ______________________ WITNESS ______________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at **www.eparmedx.com** before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

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2019 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?

If the above condition(s) is/are present, answer questions 1a-1c — If **NO** ☐ go to question 2

1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2. Do you currently have Cancer of any kind?

If the above condition(s) is/are present, answer questions 2a-2b — If **NO** ☐ go to question 3

2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐

3. Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm

If the above condition(s) is/are present, answer questions 3a-3d — If **NO** ☐ go to question 4

3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4. Do you have High Blood Pressure?

If the above condition(s) is/are present, answer questions 4a-4b — If **NO** ☐ go to question 5

4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐

5. Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes

If the above condition(s) is/are present, answer questions 5a-5e — If **NO** ☐ go to question 6

5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

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6. Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome

If the above condition(s) is/are present, answer questions 6a-6b — If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐

7. Do you have a Respiratory Disease? This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure

If the above condition(s) is/are present, answer questions 7a-7d — If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

8. Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia

If the above condition(s) is/are present, answer questions 8a-8c — If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

9. Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event

If the above condition(s) is/are present, answer questions 9a-9c — If **NO** ☐ go to question 10

9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

10. Do you have any other medical condition not listed above or do you have two or more medical conditions?

If you have other medical conditions, answer questions 10a-10c — If **NO** ☐ read the Page 4 recommendations

10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ______________________

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

2019 PAR-Q+

If you answered NO to all of the FOLLOW-UP questions (pgs. 2-3) about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ______________________________ DATE ______________________

SIGNATURE ___________________________ WITNESS ____________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________________

For more information, please contact
www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+
Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration. The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

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Key References

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APPENDIX B

RAW DATA

Demographic Data

Subject_VR	Age	Height (m)	Weight (kg)	Hand(R or L)	Race(1-6)
VR01	19	1.8	102.3	R	3
VR02	19	1.5	77.2	R	3
VR03	18	1.6	78.6	R	1
VR04	19	1.8	108.7	R	3
VR05	19	1.6	49.7	R	1
VR06	18	1.7	56.7	R	3
VR07	19	1.8	74.2	R	3
VR08	20	1.8	82.5	R	3
VR09	19	1.6	52.7	R	3
VR10	18	1.6	45	R	3
VR11	25	1.8	76.7	R	3
VR12	21	1.6	80.9	R	3
VR13	20	1.7	62	R	3
VR14	21	1.6	52.4	R	3
VR15	22	1.7	61.6	R	3
VR16	20	1.69	110.4	R	4
VR17	23	1.6	97.3	R	3
VR19	24	1.63	67.7	R	2
VR22	21	1.5	59.9	R	3

VR23	20	1.7	57.9	R	3
VR24	20	1.7	78.5	R	1
VR25	28	1.75	79.8	L	3
VR26	24	1.78	86	R	4
VR27	25	1.72	61.9	R	3
VR28	30	1.7	60.4	L	3
VR29	22	1.73	66	R	3
VR30	20	1.68	65.6	R	3
VR31	28	1.72	88.6	R	3
VR32	25	1.64	57.5	L	3
VR33	19	1.8	79.2	R	2
VR34	21	1.85	133.1	R	3
VR35	23	1.76	60.2	R	3
VR36	23	1.7	66.7	L	3
VR37	24	1.7	88.4	R	3
VR38	21	1.6	47.1	R	2
VR39	22	1.78	120.1	R	3

Subject_VR	Sex(1-2)	MS/Claustrophobia	Chronic_Pain	VR_exp(0-3)
VR01	1	0	0	0
VR02	2	0	0	0
VR03	2	0	0	1
VR04	1	0	0	0
VR05	2	0	0	0
VR06	2	0	0	0
VR07	1	0	0	1
VR08	1	0	0	0
VR09	2	0	0	0
VR10	2	0	0	0
VR11	1	0	0	0
VR12	2	0	0	0
VR13	2	0	0	0
VR14	2	0	0	0
VR15	1	0	0	0
VR16	1	0	0	0
VR17	1	0	0	1
VR19	2	0	0	0
VR22	2	0	0	1
VR23	2	0	0	0
VR24	2	0	0	0
VR25	1	0	0	0
VR26	1	0	0	0
VR27	2	0	0	0
VR28	2	0	0	0
VR29	2	0	0	0

VR30	2	0	0	0
VR31	1	0	0	0
VR32	2	0	0	0
VR33	1	0	0	0
VR34	1	0	0	1
VR35	1	0	0	0
VR36	1	0	0	0
VR37	1	0	0	0
VR38	1	0	0	0
VR39	1	0	0	0

International Physical Activity Questionnaire Data

Subject	Vigorous_days	Vigorous_minutes	Moderate_Days	Moderate_min	Walking_days	Walking_min	Sitting minutes
VR01	4	90	6	30	7	30	300
VR02	1	60	3	20	6	90	150
VR03	5	40	4	30	7	30	
VR04	5	105	6	60	7	60	10
VR05	0	0	2	30	5	20	
VR06	2	30	3	30	7	45	420
VR07	6	45	3	30	7	20	360
VR08	2	60	4	60	6	60	360
VR09	0	0	0	0	7	30	420
VR10	1	10	2	25	7	40	300
VR11	2	120	2	180	7	180	480
VR12	3	60	4	60	7	120	480
VR13	2	30	3	45	7	10	300
VR14	3	30	4	60	7	120	300
VR15	2	90	5	90	7	330	120
VR16	0	0	2	60	3	10	240
VR17	0	0	2	120	5	240	300
VR19	3	45	2	60	3	60	480
VR22	4	60	4	120	3	120	270
VR23	5	30	7	30	7	60	7
VR24	4	120	5	300	7	300	600
VR25	5	150	5	60	7	150	480
VR26	7	90	0	0	5	400	180

VR27	3	90	0	0	5	30	120
VR28	3	120	1	30	3	15	480
VR29	3	60	3	60	7	120	120
VR30	3	120	5	360	7	180	300
VR31	3	60	3	30	7	25	390
VR32	2	60	1	30	6	30	480
VR33	5	90	6	300	7	360	480
VR34	2	90	1	120	7	60	420
VR35	0	0	0	0	3	60	300
VR36	5	120	5	120	5		
VR37	4	60	4	60	7	360	240
VR38	0	0	3	90	0	0	180
VR39	4	60	2	90	3	30	420

Subject	S1_IPAQ_Vigorous	S1_IPAQ_Moderate	S1_IPAQ_Walking	S1_IPAQ_Sitting	S1_IPAQ_Total
VR01	2880	720	693	2100	4293
VR02	480	240	1782	1050	2502
VR03	1600	480	693	0	2773
VR04	4200	1440	1386	70	7026
VR05	0	240	330	0	570
VR06	480	360	1039.5	2940	1879.5
VR07	2160	360	462	2520	2982
VR08	960	960	1188	2520	3108
VR09	0	0	693	2940	693
VR10	80	200	924	2100	1204
VR11	1920	1440	4158	3360	7518
VR12	1440	960	2772	3360	5172
VR13	480	540	231	2100	1251
VR14	720	960	2772	2100	4452
VR15	1440	1800	7623	840	10863
VR16	0	480	99	1680	579
VR17	0	960	3960	2100	4920
VR19	1080	480	594	3360	2154
VR22	1920	1920	1188	1890	5028
VR23	1200	840	1386	49	3426
VR24	3840	6000	6930	4200	16770
VR25	6000	1200	3465	3360	10665
VR26	5040	0	6600	1260	11640
VR27	2160	0	495	840	2655
VR28	2880	120	148.5	3360	3148.5
VR29	1440	720	2772	840	4932

VR30	2880	7200	4158	2100	14238
VR31	1440	360	577.5	2730	2377.5
VR32	960	120	594	3360	1674
VR33	3600	7200	8316	3360	19116
VR34	1440	480	1386	2940	3306
VR35	0	0	594	2100	594
VR36	4800	2400	0	0	7200
VR37	1920	960	8316	1680	11196
VR38	0	1080	0	1260	1080
VR39	1920	720	297	2940	2937

Beat Saber Data

BS_SBP1	BS_DBP1	BS_SBP2	BS_DBP2	BS_Arise	BS_Meal	BS_Caffeine	BS_Vig_Ex	BS_Meds	BS_Health_stat	BS_Smoke
131	80	125	85	360	0	0	0	0	0	0
118	87	114	80	420	0	0	0	0	0	0
109	81	109	64	315	0	0	0	0	0	0
135	79	110	78	195	0	0	0	0	0	0
106	72	100	64	580	0	0	0	0	0	0
127	98	121	93	480	0	0	0	0	0	0
118	65	119	62	510	0	0	0	0	0	0
135	67	131	69	390	0	0	0	0	0	0
113	76	112	67	280	0	0	0	0	0	0
112	79	86	105	300	0	0	0	0	0	0
129	77	127	69	375	0	0	0	0	0	0
122	81	117	87	120	0	0	0	0	0	0
112	71	116	67	75	0	0	0	0	0	0
117	67	114	75	320	0	0	0	0	0	0
120	72	120	68	420	0	0	0	0	0	0
164	97	153	95	60	0	0	0	0	0	0
159	99	146	92	630	0	0	0	0	0	0
126	79	118	76	690	0	0	0	0	0	0
102	75	14	75	120	0	0	0	0	0	0
117	89	113	83	255	0	0	0	0	0	0
115	84	119	79	315	0	0	0	0	0	0
123	70	120	68	600	0	0	0	0	0	0

146	64	135	69	300	0	0	0	0	0	0
129	85	127	87	150	0	0	0	0	0	0
116	77	117	74	270	0	0	0	0	0	0
112	65	112	67	210	0	0	0	0	0	0
114	84	117	83	210	0	0	0	0	0	0
146	81	138	75	380	0	0	0	0	0	0
119	90	117	88	600	0	0	0	0	0	0
132	80	131	74	90	0	0	0	0	0	0
159	81	151	73	345	0	0	0	1	0	0
112	76	119	68	645	0	0	0	0	0	0
130	80	117	78	105	0	0	0	0	0	0
138	85	144	74	675	0	0	0	0	0	0
115	81	108	69	360	0	0	0	0	0	0
145	72	139	69	60	0	0	0	1	0	0

BS_PPT_arm_Fam1	BS_PPT_arm_Fam2	BS_PPT_arm_Fam_AVG	BS_PPT_thigh_Fam1	BS_PPT_thigh_Fam2	BS_PPT_thigh_Fam_AVG
4.79	4.67	4.73	5.46	4.59	5.025
4.91	4.49	4.7	8.68	7.28	7.98
3.74	3.09	3.415	5.27	5.33	5.3
5.89	6.62	6.255	6.64	7.3	6.97
6.94	7.24	7.09	10.64	11.57	11.105
4.6	5.1	4.85	5.77	7.54	6.655
6.52	7.43	6.975	13.91	14.31	14.11
9	8.31	8.655	14.2	13.04	13.62
7.88	7.38	7.63	9.57	9.35	9.46
5.15	4.89	5.02	8.07	8.84	8.455
8.45	10.17	9.31	18.18	19.35	18.765
6.78	6.49	6.635	8.98	9.72	9.35
2.73	2.93	2.83	4.35	3.82	4.085
4.79	4.91	4.85	9.96	8.22	9.09
11.76	12.93	12.345	23.31	23	23.155
4.66	3.79	4.225	6.57	4.91	5.74
7.08	6.78	6.93	10.34	10.22	10.28
14.08	15.74	14.91	24.61	18.68	21.645
9.35	9.8	9.575	12.12	13.08	12.6
4.27	3.13	3.7	5.74	5.23	5.485
5.1	5.64	5.37	8.92	11.69	10.305
7.35	9.1	8.225	15.76	12.87	14.315
22.96	21.35	22.155	23.67	25.13	24.4
11.25	10.29	10.77	18.28	15.71	16.995
7	6.12	6.56	14.24	13.16	13.7

5.55	4.48	5.015	6.03	6.99	6.51
4.09	3.59	3.84	6.21	5.63	5.92
51.27	49.28	50.275	42.91	48.8	45.855
4.56	5.11	4.835	8	7.5	7.75
17.12	18.93	18.025	24.73	21.39	23.06
18.24	17.58	17.91	20.58	21.66	21.12
5.18	7.51	6.345	8.04	7.98	8.01
10.39	10.65	10.52	22.35	17.35	19.85
6.5	7.63	7.065	13.05	11.55	12.3
10	9.48	9.74	15.58	15.29	15.435
8.22	8.11	8.165	14.11	13.94	14.025

BS_PPT-PreVR1_arm	BS_PPT-PreVR2_arm	BS_PPT_PreVR_arm_AVG	BS_PPT-PreVR1_thigh	BS_PPT-PreVR2_thigh	BS_PPT_PreVR_thigh_AVG
4.53	6.41	5.47	6.55	6.87	6.71
5.53	4.25	4.89	7.76	8.17	7.965
3.57	3.7	3.635	4.64	5.4	5.02
8.65	8.33	8.49	8.41	8.23	8.32
8.33	8.48	8.405	9.31	8.49	8.9
5.31	4.47	4.89	5.13	5.73	5.43
6.93	6.7	6.815	12.14	13.55	12.845
7.87	7.74	7.805	12.18	13.62	12.9
7.01	6.61	6.81	10.5	10.03	10.265
7.94	4.21	6.075	8.25	7.32	7.785
10.08	10.18	10.13	18.73	20.24	19.485
6.3	6.18	6.24	7.86	8.52	8.19
3.07	3.18	3.125	5.1	4.22	4.66
6.53	6.69	6.61	7.48	7.7	7.59
11.93	10.83	11.38	24.75	26.61	25.68
5.83	6.45	6.14	5.95	6.29	6.12
6.42	6.72	6.57	8.61	11.4	10.005
14.9	16.48	15.69	20.88	21.28	21.08
7.01	9.5	8.255	14.71	14.37	14.54
4.22	4.13	4.175	4.98	5.15	5.065
4.98	5.64	5.31	8.45	9.55	9
8.8	10.05	9.425	13.02	11	12.01
20.02	18.49	19.255	26.02	28.07	27.045
11.15	11.33	11.24	21.67	20.2	20.935
8.8	6.02	7.41	16.02	14.2	15.11

4.93	4.86	4.895	8.2	7.5	7.85
5.3	4.28	4.79	5.99	4.98	5.485
47.92	57.12	52.52	51.96	56.74	54.35
4.35	4.5	4.425	6.58	8.17	7.375
16.85	19.2	18.025	24.77	26.71	25.74
17.73	18.87	18.3	28.41	22.13	25.27
5.9	5.86	5.88	8.71	8.26	8.485
15.16	15.06	15.11	22.7	22.82	22.76
5.42	6.95	6.185	11.57	11.46	11.515
9.04	8.98	9.01	13.39	12.54	12.965
7.52	6.28	6.9	11.72	13.05	12.385

BS_PPT-PostVR1_arm	BS_PPT-PostVR2_arm	BS_PPT_PostVR_arm_AVG	BS_PPT-PostVR1_thigh	BS_PPT-PostVR2_thigh	BS_PPT_PostVR_thigh_AVG
4.81	6.3	5.555	8.02	7.24	7.63
4.98	5.89	5.435	7.45	7.9	7.675
3.66	4.67	4.165	6.14	6.27	6.205
4.73	4.9	4.815	7.24	7.07	7.155
8.08	7.94	8.01	12.38	13.66	13.02
5.6	5.39	5.495	5.54	5.84	5.69
7.11	6.81	6.96	11.59	14.77	13.18
8.59	9	8.795	13.87	14.75	14.31
6.33	7.13	6.73	8.86	10.61	9.735
4.21	3.64	3.925	7.95	6.93	7.44
10.88	11.52	11.2	18.69	18.36	18.525
6.17	5.4	5.785	8.56	8.66	8.61
3.1	3.08	3.09	4.4	5.02	4.71
5.71	5.56	5.635	9.38	9.72	9.55
13.16	12.07	12.615	23.75	21.63	22.69
3.3	6.09	4.695	6.1	6.49	6.295
7.95	9.13	8.54	11.65	11.7	11.675
18.33	20.46	19.395	30.35	28.71	29.53
11.44	9.97	10.705	15.54	18.29	16.915
3.46	3.97	3.715	5.2	6.06	5.63
3.68	7	5.34	10.47	9.59	10.03
6.94	8.99	7.965	11.25	11.4	11.325
28.25	29.18	28.715	35.07	29.51	32.29
10.89	11.57	11.23	16.95	18.35	17.65
6.16	5.4	5.78	14.09	14.96	14.525

6.12	6.03	6.075	8.2	8.04	8.12
5.77	6.18	5.975	7.26	7.76	7.51
46.03	50.66	48.345	53.09	51.8	52.445
4.17	4.34	4.255	6.09	5.42	5.755
18.95	20.56	19.755	24.12	26.69	25.405
20.47	19.11	19.79	25.83	25.84	25.835
6.83	5.38	6.105	8.65	7.53	8.09
14.35	15.23	14.79	23.65	22.2	22.925
6.65	6.79	6.72	10.12	11.43	10.775
13.8	13.65	13.725	14.82	18.82	16.82
7.76	9.56	8.66	11.92	13.04	12.48

Age_HR	BS_Resting_HR	BS_HR_Base	BS_HR_5min	BS_HR_10min	BS_HR_15min	BS_HRmax	BS_HRavg	BS_RPE_MAX	BS_RPE_AVG	BS_%HRR
19	86	94	98	100	100	113	97	12	10	9.57
19	77	99	108	130	109	131	108	13	11	25.00
18	89	91	91	91	94	103	94	11	10	4.42
19	97	103	117	117	115	131	115	11	9	17.31
19	105	109	123	123	117	136	122	8	7	17.71
18	80	91	94	109	96	120	98	11	9	14.75
19	67	72	78	78	76	90	77	12	10	7.46
20	76	81	84	90	89	113	90	9	8	11.29
19	93	101	104	101	102	112	106	10	8	12.04
18	87	106	102	105	108	117	99	13	12	10.43
25	89	94	104	104	96	125	101	13	11	11.32
21	74	87	87	101	107	119	99	8	7	20.00
20	94	103	106	108	115	127	111	127	111	16.04
21	53	66	63	64	66	90	69	8	8	10.96
22	59	73	81	75	67	85	72	13	11	9.35
20	92	102	106	102	103	118	107	12	11	13.89
23	89	99	97	99	103	115	101	13	12	11.11
24	69	72	82	78	79	99	82	8	8	10.24
21	77	78	93	93	92	110	93	11	11	13.11
20	86	85	91	92	92	103	92	12	10	5.26
20	60	70	81	83	84	108	85	11	9	17.86
28	49	65	63	65	70	81	67	9	7	12.59
24	62	67	71	69	74	84	70	8	7	5.97
25	83	96	111	99	102	120	102	11	10	16.96
30	74	102	110	105	111	118	108	9	9	29.31

22	62	78	85	78	87	104	85	15	12	16.91
20	83	96	98	105	108	120	104	10	9	17.95
28	53	65	88	70	80	97	75	9	8	15.83
25	78	86	107	108	106	130	106	13	11	23.93
19	58	68	76	77	83	90	78	14	12	13.99
21	92	101	102	101	102	113	101	11	9	8.41
23	82	88	119	124	93	135	104	14	13	19.13
23	73	77	87	78	82	95	79	8	7	4.84
24	76	79	88	89	89	97	88	9	8	10.00
21	69	78	90	85	90	108	89	10	10	15.38
22	70	80	83	72	73	87	77	11	9	5.47

BS_VAS	BS*PACES_Enjoy	BS_PACES_Like	BS_PACES_Fun	BS_PACES_Good	BS*PACES_Frustrated	BS_PACES_total
8.5	7	6	7	7	6	33
7.5	7	6	6	6	7	32
7.53	6	5	4	7	6	28
6.5	7	7	6	6	6	32
6.5	6	7	7	7	4	31
6.6	2	6	6	3	7	24
8	7	7	7	7	6	34
6.5	6	5	4	7	5	27
9.6	7	7	7	7	6	34
8.9	7	7	6	7	7	34
7.7	7	7	7	5	7	33
7.3	6	6	6	4	3	25
8.9	7	7	6	7	7	34
9.9	7	7	7	7	7	35
9.4	7	7	7	7	7	35
9.7	7	6	7	7	7	34
10	7	7	7	6	4	31
10	7	7	7	7	7	35
7.2	7	7	7	7	7	35
8.4	7	7	7	7	7	35
9.1	7	6	6	6	6	31
8.9	7	7	7	7	7	35
0.8	4	4	4	6	7	25
8.7	6	5	6	7	7	31
6.3	6	5	5	5	6	27
9.1	7	7	7	7	5	33

6.6	6	5	5	7	7	30
6.5	6	7	5	6	6	30
8.9	7	7	7	6	6	33
9	7	6	7	6	7	33
9.7	7	7	7	7	7	35
7	7	7	7	6	5	32
6.9	7	7	6	4	7	31
7.3	6	6	6	6	7	31
10	6	7	7	5	7	32
8.2	7	7	7	7	7	35

BS_ACTG_WRIST_%Sed	BS_ACTG_WRIST_%Light	BS_ACTG_WRIST_%Mod	BS_ACTG_WRIST_%Vig	BS_ACTG_WRIST_%MVPA
9.09	18.57	34.7	20.61	72.34
7.94	10.24	20.49	19.97	81.82
5.12	14.6	38.54	21.51	80.28
2.69	5.12	15.62	17.93	92.19
7.68	12.8	29.32	29.83	79.51
10.88	14.85	34.7	34.7	74.26
4.61	9.09	33.29	24.58	86.3
7.3	14.6	38.28	23.94	78.1
7.81	15.75	42	23.94	76.44
10.76	16.9	46.99	20.87	72.34
4.99	13.83	28.43	22.41	81.18
5.91	15.71	32.16	28.84	78.37
5.63	11.78	27.27	27.02	82.59
12.16	25.48	48.78	12.04	62.36
5.63	16.01	39.18	27.02	78.36
3.07	14.47	35.85	29.96	82.46
3.71	6.79	23.82	27.02	89.5
4.99	9.22	24.84	28.3	85.79
1.79	8.07	23.94	24.71	90.14
5.63	12.93	40.33	23.05	18.05
7.81	9.48	20.23	23.43	82.71
8.19	8.71	23.3	33.16	83.1
14.98	32.39	45.45	6.27	52.62
1.79	7.43	20.87	22.54	90.78
11.01	14.34	41.87	22.02	74.65

4.23	10.76	32.65	26.38	85.02
18.44	41.49	36.62	3.2	40.08
2.05	6.91	17.16	19.59	91.04
1.79	10.5	24.58	25.35	87.71
3.71	10.37	25.99	25.48	85.92
4.48	9.6	28.55	25.22	85.92
6.79	12.68	27.4	25.74	80.54
5.38	9.35	27.02	27.02	85.28
5.12	8.58	22.41	21.25	86.3
7.04	14.21	37.13	25.35	78.75

BS_ACTG_WAIST_%Sed	BS_ACTG_WAIST_%Light	BS_ACTG_WAIST_%Mod	BS_ACTG_WAIST_%Vig	BS_ACTG_WAIST_%MVPA
96.41	1.79	1.66	0.13	1.79
73.88	20.61	5.25	0.13	5.51
84.12	15.24	0.64	0	0.64
67.73	29.19	3.07	0	3.07
81.05	17.29	1.54	0.13	1.66
94.1	4.36	1.28	0.13	1.54
97.18	2.18	0.64	0	0.64
94.88	4.1	1.02	0	1.02
96.16	2.82	1.02	0	1.02
98.98	1.02	0	0	0
96.93	1.79	1.15	0.13	1.28
91.42	8.07	0.51	0	0.51
92.32	7.55	0.13	0	0.13
84.76	13.7	1.54	0	1.54
98.46	1.54	0	0	0
87.58	11.65	0.77	0	0.77
97.31	2.56	0.13	0	0.13
67.7	23.09	8.56	0.65	9.21
83.61	11.14	4.35	0.9	5.25
95.39	3.33	1.28	0	1.28
75.03	19.46	5.12	0.38	5.51
81.18	16.01	2.82	0	2.82
93.98	5.51	0.51	0	0.51
82.97	13.06	3.84	0.13	3.97
95.39	3.84	0.77	0	0.77

77.21	20.61	2.18	0	2.18
95.26	4.23	0.51	0	0.51
92.57	6.66	0.77	0	0.77
56.98	37.52	5.51	0	5.51
52.5	44.3	3.2	0	3.2
88.86	9.22	1.92	0	1.92
95.65	2.94	1.41	0	1.41
96.26	2.22	1.53	0	1.53
76.95	17.8	4.74	0.38	5.25
79.74	18.21	2.05	0	2.05

BS_ACTG_THIGH_%Sed	BS_ACTG_THIGH_%Light	BS_ACTG_THIGH_%Mod	BS_ACTG_THIGH_%Vig	BS_ACTG_THIGH_%MVPA
96.41	2.18	1.28	0.13	1.41
81.95	15.49	2.3	0.26	2.56
90.01	9.6	0.38	0	0.38
71.32	24.84	3.46	0.26	3.84
81.56	15.49	2.05	0.64	2.94
95.26	2.56	1.28	0.77	2.18
99.49	0.51	0	0	0
97.31	1.92	0.77	0	0.77
95.9	3.97	0.13	0	0.13
98.59	1.41	0	0	0
95.65	2.43	1.66	0.26	1.92
97.44	2.3	0.26	0	0.26
98.59	1.41	0	0	0
82.33	16.9	0.77	0	0.77
99.87	0.13	0	0	0
93.85	6.15	0	0	0
99.49	0.51	0	0	0
70.56	26.2	2.98	0.26	3.24
80.28	17.67	2.05	0	2.05
96.41	2.94	0.51	0.13	0.64
90.52	7.68	1.79	0	1.79
82.97	14.47	2.3	0.26	2.56
93.98	5.76	0.26	0	0.26
86.17	11.91	1.92	0	1.92
96.41	3.33	0.26	0	0.26
87.2	11.01	1.54	0.26	1.79

93.73	5.38	0.9	0	0.9
91.26	8.32	0.42	0	0.42
83.61	15.75	0.64	0	0.64
84.76	14.34	0.9	0	0.9
86.81	12.68	0.51	0	0.51
97.82	2.18	0	0	0
98.98	1.02	0	0	0
77.21	18.05	2.82	1.92	4.74
57.62	39.18	2.94	0.26	3.2

Holopoint Data

HP_SBP1	HP_DBP1	HP_SBP2	HP_DBP2	HP_Arise	HP_Meal	HP_Caffeine	HP_Vig_Ex	HP_Meds	HP_Health_stat	HP_Smoke
137	84	124	85	345	0	0	0	0	0	0
119	76	122	82	405	0	0	0	0	0	0
120	75	115	74	330	0	0	0	0	0	0
137	88	129	90	115	0	0	0	0	0	0
108	65	102	61	415	0	0	0	0	0	0
123	96	125	94	435	0	0	0	0	0	0
130	62	134	61	650	0	0	0	0	0	0
152	74	144	64	435	0	0	0	0	0	0
110	71	108	69	395	0	0	0	0	0	0
108	74	103	71	480	0	0	0	0	0	0
123	81	120	79	270	0	0	0	0	0	0
106	84	107	78	120	0	0	0	0	0	0
120	78	121	79	90	0	0	0	0	0	0
127	83	117	77	60	0	0	0	0	0	0
113	65	113	62	90	0	0	0	0	0	0
164	93	161	90	60	0	0	0	0	0	0
142	94	142	95	510	0	0	0	0	0	0
119	71	120	76	480	0	0	0	0	0	0
113	61	107	66	150	0	0	0	1	0	0
105	76	99	66	360	0	0	0	0	0	0
127	75	124	81	330	0	0	0	0	0	0
123	70	124	67	630	0	0	0	0	0	0

159	76	142	73	180	0	0	0	0	0	0
112	72	118	76	165	0	0	0	0	0	0
119	78	111	77	180	0	0	0	0	0	0
112	72	111	66	285	0	0	0	0	0	0
116	76	112	77	380	0	0	0	0	0	0
145	96	149	91	240	0	0	0	0	0	0
123	88	114	80	540	0	0	0	0	0	0
126	72	122	65	390	0	0	0	0	0	0
149	77	144	80	180	0	0	0	0	0	0
121	80	123	82	705	0	0	0	0	0	0
123	72	142	77	70	0	0	0	0	0	0
142	77	137	65	675	0	0	0	0	0	0
130	70	137	66	360	0	0	0	0	0	0
143	68	136	61	105	0	0	0	1	0	0

HP_PPT_arm_Fam1	HP_PPT_arm_Fam2	HP_PPT_arm_Fam_AVG	HP_PPT_thigh_Fam1	HP_PPT_thigh_Fam2	HP_PPT_thigh_Fam_AVG
3.41	3.76	3.585	7.41	7.2	7.305
3.58	3.65	3.615	5.13	5.08	5.105
3.16	3.17	3.165	4.86	4.88	4.87
8.34	8.86	8.6	15.08	12.68	13.88
7.11	6.53	6.82	9.81	9.97	9.89
3.8	5.18	4.49	5.62	6.41	6.015
5.66	6.19	5.925	7.16	7.92	7.54
6.25	5.39	5.82	8	8.75	8.375
6.15	6.03	6.09	7.11	7.45	7.28
5.01	4.48	4.745	9.68	8.26	8.97
10.22	10.78	10.5	18.74	18.52	18.63
9.15	10.48	9.815	13.05	12.41	12.73
2.73	2.47	2.6	5	4.44	4.72
4.63	5	4.815	8.2	7.74	7.97
13.45	15.55	14.5	20.61	25.33	22.97
5.17	3.55	4.36	6.88	6.05	6.465
4.75	4.85	4.8	8.24	8.15	8.195
22.09	22.13	22.11	27.63	31.37	29.5
9.39	9.2	9.295	15.02	13.07	14.045
4.89	5.16	5.025	6.39	5.86	6.125
5.77	6.28	6.025	9.86	9.87	9.865
8.13	7.77		16.3	15.41	
8.64	8.83	8.735	17.02	17.27	17.145
8.96	7.65	8.305	15.73	13.27	14.5
5.74	5.07	5.405	11.27	11.36	11.315

4.31	4.36	4.335	5.93	6.63	6.28
4.2	3.66	3.93	5.33	4.57	4.95
51.03	42.83	46.93	42.05	45.61	43.83
4.04	3.57	3.805	7.48	5.66	6.57
13.44	13.36	13.4	19.28	17.81	18.545
14.91	11.49	13.2	18.67	20.68	19.675
4.7	5.53	5.115	12.07	12.07	12.07
15.51	14.95	15.23	21.81	23.46	22.635
9.45	9.39	9.42	15.51	13.43	14.47
10.98	10.85	10.915	14.5	13.27	13.885
9.79	7.7	8.745	14.51	12.17	13.34

HP_PPT-PreVR1_arm	HP_PPT-PreVR2_arm	HP_PPT_PreVR_arm_AVG	HP_PPT-PreVR1_thigh	HP_PPT-PreVR2_thigh	HP_PPT_PreVR_thigh_AVG
4.47	3.1	3.785	6.73	7.45	7.09
4.26	3.65	3.955	5.3	5.59	5.445
2.68	3.25	2.965	5.26	6.41	5.835
8.46	9.85	9.155	12.83	13.28	13.055
7.57	6.47	7.02	7.26	8.43	7.845
3.41	3.62	3.515	4.13	3.54	3.835
5.63	5.4	5.515	8.16	8.37	8.265
4.1	4.23	4.165	6.53	6.96	6.745
5.95	6.84	6.395	7.58	9.04	8.31
4.14	4.4	4.27	9.27	9.84	9.555
10.12	10.08	10.1	18.56	20.06	19.31
9.53	10.98	10.255	13.84	13.15	13.495
2.87	2.94	2.905	4.26	4.45	4.355
4.93	5.4	5.165	9.99	11.75	10.87
12.38	11.57	11.975	21.8	21.4	21.6
4.31	3.77	4.04	6.56	4.84	5.7
4.96	4.58	4.77	7.87	6.57	7.22
21.16	24.8	22.98	29.86	34.38	32.12
8.56	10.57	9.565	15.22	13.66	14.44
4.89	3.03	3.96	5.86	6.36	6.11
7.82	7.98	7.9	12.13	11.81	11.97
6.27	5.35		10.62	13.29	
12.78	11.23	12.005	15.94	17.72	16.83
9.2	8.45	8.825	11.98	13.32	12.65
7.3	8.23	7.765	16.35	10.67	13.51

5.2	4.01	4.605	7	5.77	6.385
4.09	4.82	4.455	6.4	5.08	5.74
39.84	43.35	41.595	46.26	51.74	49
3.45	3.79	3.62	5.63	5.5	5.565
13.07	9.67	11.37	18.84	17.07	17.955
13.33	14.94	14.135	20.67	19.14	19.905
4.62	4.87	4.745	10.22	8.71	9.465
12.83	15.67	14.25	21.59	18.36	19.975
9.89	8.69	9.29	14.36	13.04	13.7
11.26	9.99	10.625	12.53	12.24	12.385
9.39	7.77	8.58	14.55	15.7	15.125

HP_PPT-PostVR1_arm	HP_PPT-PostVR2_arm	HP_PPT_PostVR_arm_AVG	HP_PPT-PostVR1_thigh	HP_PPT-PostVR2_thigh	HP_PPT_PostVR_thigh_AVG
3.9	4.75	4.325	7.46	8.42	7.94
4.55	3.89	4.22	4.15	4.09	4.12
2.86	2.64	2.75	4.29	5.12	4.705
10.78	12.52	11.65	16.68	15.86	16.27
7.37	7.29	7.33	9.88	11.01	10.445
5.02	5.37	5.195	4.91	4.84	4.875
5.65	6.19	5.92	8.28	9.25	8.765
4.77	6	5.385	11.5	11.58	11.54
5.73	6.43	6.08	8.48	7.86	8.17
5.65	3.38	4.515	12.54	11.98	12.26
13.1	11.74	12.42	20.51	19.14	19.825
9.76	11.29	10.525	17.92	15.91	16.915
2.77	2.55	2.66	5.63	5.47	5.55
6.19	6.01	6.1	11.97	12.82	12.395
14.11	13.23	13.67	20.57	21.39	20.98
3.75	2.9	3.325	5.9	4.1	5
4.98	4.87	4.925	8.95	9.13	9.04
24.8	28.49	26.645	35.53	39.51	37.52
9.24	10.96	10.1	17.35	14.39	15.87
4.23	4.51	4.37	5.44	5.7	5.57
8.68	9.59	9.135	11.85	10.11	10.98
7.78	8.41	8.095	9.68	12.44	11.06
16.62	17.32	16.97	23.89	21.64	22.765
7.63	8.73	8.18	15.93	14.5	15.215
6.7	5.52	6.11	16.82	13.25	15.035

4.21	6.32	5.265	5.76	6.71	6.235
5.19	3.98	4.585	6.62	4.82	5.72
41.89	50.35	46.12	58.62	59.17	58.895
4.19	4.26	4.225	7.26	7.28	7.27
9.69	13.18	11.435	19.89	19.98	19.935
12.6	15.87	14.235	22.02	20.16	21.09
4.76	4.76	4.76	12.67	11.95	12.31
11.66	11.29	11.475	19.24	20.53	19.885
10.71	11.8	11.255	14.95	16.12	15.535
10.24	9.38	9.81	14.1	13.34	13.72
8.73	8.84	8.785	16.32	16.39	16.355

Age_HR	HP_Resting_HR	HP_HR_Base	HP_HR_5min	HP_HR_10min	HP_HR_15min	HP_HRmax	HP_HRavg	HP_RPE_MAX	HP_RPE_AVG	HP_%HRR
19	75	76	106	113	97	122	107	15	12	25.40
19	80	94	139	156	134	159	143	15	13	52.07
18	86	89	102	102	102	112	102	15	14	13.79
19	92	97	116	144	136	176	153	15	14	55.96
19	102	117	125	126	125	134	123	12	11	21.21
18	95	108	143	160	158	170	148	13	12	49.53
19	71	81	104	118	129	135	116	15	13	34.62
20	67	83	104	108	111	122	109	13	11	31.58
19	90	100	102	107	103	113	105	11	9	13.51
18	75	96	106	110	113	120	108	13	11	25.98
25	83	86	104	100	107	116	102	15	13	16.96
21	89	116	143	140	137	154	139	10	9	45.45
20	89	107	109	118	114	126	111	12	11	19.82
21	62	68	91	85	81	89	81	11	9	13.87
22	70	83	100	105	114	117	102	15	13	25.00
20	85	93	128	133	140	151	133	16	15	41.74
23	75	77	105	100	94	108	99	9	8	19.67
24	67	77	85	79	81	92	82	10	9	11.63
21	69	81	104	99	91	108	95	12	12	20.00
20	77	74	85	93	86	96	88	13	11	8.94
20	84	85	104	107	106	126	105	12	10	18.10
28	50	62	82	79	81	88	76	10	8	18.31
24	68	69	79	77	79	93	75	9	7	5.47
25	65	108	96	115	95	124	101	13	11	27.69
30	85	95	115	120	115	124	110	14	12	23.81

22	58	79	96	100	92	106	94	15	14	25.71
20	79	110	101	117	119	133	117	15	14	31.40
28	68	77	138	161	144	161	137	13	12	55.65
25	64	84	133	130	124	134	120	12	10	42.75
19	61	67	118	125	117	129	118	15	13	40.71
21	85	99	122	128	124	138	124	15	13	34.21
23	76	80	106	116	103	119	105	11	10	23.97
23	60	76	91	118	110	123	99	13	11	28.47
24	74	82	93	111	95	115	103	12	11	23.77
21	81	81	118	116	118	118	117	16	15	30.51
22	68	73	101	114	132	136	107	15	11	30.00

HP_VAS	HP*PACES_Enjoy	HP_PACES_Like	HP_PACES_Fun	HP_PACES_Good	HP*PACES_Frustrated	HP_PACES_total
8.3	6	7	7	6	5	31
5.6	3	5	6	5	3	22
3.9	6	5	4	4	3	22
9.8	7	7	7	7	6	34
5.9	4	4	4	4	5	21
6	3	4	4	4	7	22
6.2	3	6	6	7	5	27
7.5	7	6	5	7	6	31
8.3	7	7	6	7	7	34
6.5	6	5	5	7	5	28
8.6	7	7	7	6	6	33
7.9	6	6	6	6	5	29
8.2	7	7	6	7	5	32
9.4	7	7	7	7	7	35
9.6	7	7	7	7	7	35
10	6	7	7	6	7	33
10	7	7	7	7	7	35
7.6	6	7	5	7	7	32
5.7	7	7	6	7	7	34
8.3	7	7	6	7	5	32
8.9	7	7	7	7	7	35
6.5	6	5	5	6	5	27
7.8	7	7	7	6	6	33
6.9	6	5	4	7	3	25
7.5	6	6	6	5	6	29
7.2	6	6	6	6	6	30

1	5	2	4	2	1	14
10	7	7	7	6	6	33
8.3	7	6	7	6	7	33
7.4	6	5	6	7	7	31
7.5	6	6	6	6	7	31
6.8	5	5	5	4	5	24
10	7	6	6	6	6	31
6.4	5	6	5	5	6	27
7.8	6	5	6	5	6	28
9.6	7	7	6	6	6	32

HP_ACTG_WRIST_%Sed	HP_ACTG_WRIST_%Light	HP_ACTG_WRIST_%Mod	HP_ACTG_WRIST_%Vig	HP_ACTG_WRIST_%MPVA
0.77	11.01	50.6	28.04	88.22
1.66	11.27	31.88	33.42	87.07
1.02	20.61	63.64	12.8	78.36
0.26	1.54	16.68	23.94	98.21
1.92	22.79	46.99	23.82	75.29
1.28	13.06	49.04	26.25	10.37
0.51	11.01	37.13	32.01	88.48
1.54	8.19	42.89	26.63	90.27
10.76	26.25	43.15	17.8	63
3.69	29.01	52.44	13.79	67.3
0.51	1.92	17.8	16.52	97.57
0.64	13.3	49.74	23.91	86.06
0	6.4	57.23	30.86	93.6
2.56	11.52	57.62	25.1	85.92
0.51	1.79	26.38	33.67	97.7
0.26	2.69	20.49	25.1	97.06
1.66	7.3	28.17	23.3	91.04
2.82	21.64	60.18	12.93	75.54
1.66	22.54	61.33	11.65	75.8
3.71	16.65	48.66	20.23	79.64
2.69	27.14	54.29	12.68	70.17
1.66	9.86	48.4	31.63	88.48
2.05	10.5	29.58	31.5	87.45

0.9	4.61	30.35	35.34	94.49
2.69	24.97	62.61	8.71	72.34
0.64	1.41	14.85	3047	97.95
1.11	15.67	54.51	23.44	83.22
0.64	3.33	25.61	32.91	96.03
1.15	8.45	40.08	27.53	90.4
0.13	2.18	18.82	27.53	97.7
0.29	3.33	16.77	19.72	96.29
0.26	4.23	33.55	39.44	95.52
0.9	3.2	22.92	34.19	95.9
0.51	8.32	48.91	30.47	91.17

HP_ACTG_WAIST_%Sed	HP_ACTG_WAIST_%Light	HP_ACTG_WAIST_%Mod	HP_ACTG_WAIST_%Vig	HP_ACTG_WAIST_%MVPA
43.15	51.73	4.99	0	5.12
40.85	38.8	16.52	3.46	20.36
78.75	21	0.26	0	0.26
2.3	37.64	52.88	6.4	60.05
95.26	4.74	0	0	0
56.42	15.69	12.71	11.02	27.89
38.67	53.27	7.68	0.38	8.07
34.31	56.47	9.22	0	9.22
97.57	2.3	0.13	0	0.13
92.83	7.04	0.13	0	0.13
76.7	23.3	0	0	0
26.25	47.63	24.2	1.92	26.12
99.23	0.77	0	0	0
96.93	3.07	0	0	0
25.86	52.11	20.87	1.02	22.02
42.64	50.58	6.27	0.51	6.79
54.29	43.28	2.43	0	2.43
57.49	35.6	6.15	0.77	6.91
88.73	11.27	0	0	0
79.77	14.72	4.74	0.64	5.51
43.92	47.25	8.45	0.38	8.83
72.73	27.27	0	0	0
87.2	7.94	2.18	2.3	4.87
53.14	26.5	19.85	0.51	20.36

43.02	40.2	14.72	1.92	16.77
55.95	37.64	6.4	0	6.4
3.97	33.16	54.03	8.19	62.87
37	39.95	22.02	1.02	23.05
11.65	46.09	40.59	1.54	42.25
28.55	48.78	22.02	0.64	22.66
21.38	65.17	12.93	0.51	13.44
31.5	48.78	16.77	2.69	19.72
40.2	39.82	19.97	0	19.97
26.38	32.78	30.22	10.24	40.85
23.56	42.13	25.1	6.27	34.31

HP_ACTG_THIGH_%Sed	HP_ACTG_THIGH_%Light	HP_ACTG_THIGH_%Mod	HP_ACTG_THIGH_%Vig	HP_ACTG_THIGH_%MVPA
24.97	50.3	23.9	0.83	24.73
48.27	41.1	9.35	1.15	10.63
63.51	35.6	0.9	0	0.9
3.2	26.89	54.93	13.83	69.91
81.31	17.67	1.02	0	1.02
45.58	40.2	13.7	0.51	14.21
33.03	52.88	13.96	0.13	14.08
14.21	61.72	23.94	0.13	24.07
80.28	19.72	0	0	0
63.26	34.13	2.62	0	2.62
75.54	24.46	0	0	0
51.98	44.17	3.84	0	3.84
89.88	10.12	0	0	0
83.48	16.52	0	0	0
19.97	55.19	24.33	0.51	24.84
30.6	60.05	9.22	0.13	9.35
75.29	23.56	1.15	0	1.15
43.28	50.83	5.89	0	5.89
71.96	26.38	1.66	0	1.66
64.28	31.75	3.97	0	3.97
38.16	52.24	9.22	0.38	9.6
58.9	39.44	1.66	0	1.66
83.78	11.65	4.23	0.51	4.87
60.18	35.08	4.74	0	4.74

40.33	53.14	6.15	0.38	6.53
49.55	46.99	3.46	0	3.46
6.66	29.19	53.91	10.12	64.15
31.24	58.13	10.5	0.13	10.63
9.22	36.88	47.5	6.27	53.91
30.47	59.15	10.37	0	10.37
12.29	53.01	32.91	1.79	37.7
15.11	52.24	32.01	0.64	32.65
80.15	19.72	0.13	0	0.13
25.22	46.09	24.97	3.07	26.68
14.47	32.91	46.61	5.76	52.62

Hot Squat Data

HS_SBP1	HS_DBP1	HS_SBP2	HS_DBP2	HS_Arise	HS_Meal	HS_Caffeine	HS_Vig_Ex	HS_Meds	HS_Health_stat	HS_Smoke
137	84	135	88	360	0	0	0	0	0	0
117	74	111	73	390	0	0	0	0	0	0
122	74	122	65	330	0	0	0	0	0	0
143	88	144	88	135	0	0	0	0	0	0
112	74	109	65	560	0	0	0	0	0	0
127	88	126	88	390	0	0	0	0	0	0
116	64	119	61	510	0	0	0	0	0	0
128	64	127	64	390	0	0	0	0	0	0
119	78	117	80	300	0	0	0	0	0	0
113	76	110	74	400	0	0	0	0	0	0
130	83	129	81	120	0	0	0	0	0	0
119	89	116	89	120	0	0	0	0	0	0
113	69	107	65	290	0	0	0	0	0	0
114	73	109	70	60	0	0	0	0	0	0
113	68	112	65	105	0	0	0	0	0	0
163	99	154	81	40	0	0	0	0	0	0
144	88	135	83	630	0	0	0	0	0	0
102	72	105	74	510	0	0	0	0	0	0
112	74	114	70	150	0	0	0	1	0	0
118	71	119	78	300	0	0	0	0	0	0
124	82	120	71	45	0	0	0	0	0	0
131	72	132	69	570	0	0	0	0	0	0

134	65	134	60	110	0	0	0	0	0	0
109	71	105	71	120	0	0	0	0	0	0
110	69	113	76	75	0	0	0	0	0	0
114	69	117	69	255	0	0	0	0	0	0
118	75	118	74	180	0	0	0	0	0	0
133	73	124	71	360	0	0	0	0	0	0
125	92	115	88	180	0	0	0	0	0	0
136	85	135	71	100	0	0	0	0	0	0
156	89	159	87	90	0	0	0	1	0	0
110	66	109	71	630	0	0	0	0	0	0
124	75	123	72	60	0	0	0	0	0	0
143	76	139	68	705	0	0	0	0	0	0
124	75	127	74	360	0	0	0	0	0	0
135	70	132	70	60	0	0	0	1	0	0

HS_PPT_arm_Fam1	HS_PPT_arm_Fam2	HS_PPT_arm_Fam_AVG	HS_PPT_thigh_Fam1	HS_PPT_thigh_Fam2	HS_PPT_thigh_Fam_AVG
7.99	7.83	7.91	13.67	12.67	13.17
4.4	4.69	4.545	6.63	6.74	6.685
3.86	3.47	3.665	4.61	4.69	4.65
12.08	13.36	12.72	18.86	17.12	17.99
8.2	7.38	7.79	9.31	13.9	11.605
4.92	4.79	4.855	6.06	5.95	6.005
6.27	5.05	5.66	10.48	9.1	9.79
11.45	12.48	11.965	16.55	14.59	15.57
6.58	6.17	6.375	8.08	7.03	7.555
5.62	4.04	4.83	8.95	8.91	8.93
13.05	15.88	14.465	34.21	27.59	30.9
8.03	8.29	8.16	9.75	9.87	9.81
3.03	3.23	3.13	3.75	4	3.875
5.66	4.8	5.23	12.29	9.59	10.94
13.17	11.94	12.555	25.32	25.37	25.345
5.37	4.92	5.145	6.68	6.02	6.35
5.73	6.35	6.04	11.68	10.36	11.02
12.22	18.52	15.37	25.65	26.21	25.93
6.1	6.88	6.49	10.4	9.89	10.145
5.05	3.89	4.47	6.09	6.82	6.455
5.7	6.3	6	5.58	4.75	5.165
6.56	6.28	6.42	10.66	9.61	10.135
19.01	15.78	17.395	21.71	22.58	22.145
9.93	9.48	9.705	10.59	16.6	13.595
3.59	5.19	4.39	7.36	5.89	6.625

5.42	6.46	5.94	6.33	7.33	6.83
4.95	4.3	4.625	5.65	5	5.325
44.26	35.22	39.74	56.12	56.1	56.11
4.38	4.97	4.675	7.78	7.05	7.415
21.89	23.2	22.545	27.99	23.17	25.58
16.03	13.84	14.935	23.17	22.99	23.08
6.7	6.67	6.685	13.46	14.08	13.77
9.58	10.69	10.135	16.22	16.75	16.485
10.65	9.96	10.305	19.37	15.29	17.33
7.71	8.89	8.3	14.57	11.37	12.97
9.66	9.36	9.51	18.06	18.54	18.3

HS_PPT-PreVR1_arm	HS_PPT-PreVR2_arm	HS_PPT_PreVR_arm_AVG	HS_PPT-PreVR1_thigh	HS_PPT-PreVR2_thigh	HS_PPT_PreVR_thigh_AVG
10.12	8.95	9.535	16.36	15.1	15.73
3.57	3.38	3.475	5.29	6.39	5.84
3.89	4.3	4.095	3.4	4.66	4.03
14.22	13.04	13.63	25.04	21.14	23.09
6.8	6.34	6.57	11.58	13.15	12.365
5.12	5.05	5.085	6.35	5.55	5.95
5.78	5.96	5.87	9.41	9	9.205
9.14	9.26	9.2	12.61	12.7	12.655
6.44	6.2	6.32	9.58	7.65	8.615
4.76	4.63	4.695	8.21	10.92	9.565
15.56	16.17	15.865	34.83	31.29	33.06
8.11	8.12	8.115	13.27	10.78	12.025
2.51	2.71	2.61	3.58	3.85	3.715
4.91	5.67	5.29	15.8	14	14.9
11.57	11.89	11.73	31.11	24.45	27.78
5.31	4.38	4.845	6.07	5.4	5.735
5.4	4.97	5.185	9.49	9.76	9.625
12.38	15.95	14.165	20.64	21.6	21.12
7.25	5.53	6.39	9.52	9.95	9.735
4.52	4.12	4.32	7.98	6.95	7.465
5.95	5.69	5.82	6.91	6.33	6.62
6.08	5.38	5.73	9.1	9.55	9.325
16.38	17.46	16.92	19.41	20.53	19.97
11.14	11	11.07	19.39	19.45	19.42
5.43	4.17	4.8	6.07	7.65	6.86

6.08	5.69	5.885	7.46	8.31	7.885
4.76	4.28	4.52	6.21	6.14	6.175
43.65	47.21	45.43	51.75	46.91	49.33
3.18	4.03	3.605	5.94	7.08	6.51
18.45	17.81	18.13	22.65	24.38	23.515
15.4	15.07	15.235	22.9	24.04	23.47
7.57	9.17	8.37	13.7	13.44	13.57
10.74	8.9	9.82	16.61	18.27	17.44
9.99	12.48	11.235	18.79	16.61	17.7
9.82	9.37	9.595	14.05	14.9	14.475
10	8.11	9.055	17.56	14.94	16.25

HS_PPT-PostVR1_arm	HS_PPT-PostVR2_arm	HS_PPT_PostVR_arm_AVG	HS_PPT-PostVR1_thigh	HS_PPT-PostVR2_thigh	HS_PPT_PostVR_thigh_AVG
8.4	9.76	9.08	18.11	14.82	16.465
5.42	5.54	5.48	7.46	6.59	7.025
2.23	2.72	2.475	4.19	4.76	4.475
14.1	12.47	13.285	22.27	21.83	22.05
10.88	10.04	10.46	12.07	14.43	13.25
3.24	4.58	3.91	6.3	6.52	6.41
6.63	7.47	7.05	11.04	10.12	10.58
11.43	10.63	11.03	18.54	17.69	18.115
6.1	5.91	6.005	8.86	9.28	9.07
6.36	5.37	5.865	11.08	11.52	11.3
15.71	14.37	15.04	25.12	31.33	28.225
8.23	8.05	8.14	12.47	13.5	12.985
2.44	2.66	2.55	4.86	4.32	4.59
6.44	7.01	6.725	16.88	16.67	16.775
14.01	13.13	13.57	24.63	23.42	24.025
5.53	4.3	4.915	7.61	6.67	7.14
6.17	6.61	6.39	9.53	11.09	10.31
13.85	21.1	17.475	33.19	36.28	34.735
7.49	5.73	6.61	12.92	9.29	11.105
4.86	5.12	4.99	6.34	7.37	6.855
6.66	9.88	8.27	7.8	7.27	7.535
4.79	4.69	4.74	9.28	8.9	9.09
19.76	18.65	19.205	31.46	30.48	30.97
13	13.08	13.04	20.99	19.68	20.335
6.02	4.33	5.175	10.52	7.44	8.98

4.86	6.2	5.53	9.16	10.26	9.71
7.66	4.46	6.06	8.26	7.85	8.055
36.83	45.73	41.28	55.2	57.67	56.435
3.45	4.51	3.98	7.15	7.06	7.105
19.12	19.39	19.255	30.55	33.32	31.935
21.53	19.45	20.49	21.93	31.01	26.47
6.11	7.3	6.705	22.23	18.68	20.455
10.4	11.94	11.17	17.41	20.93	19.17
9.88	10.38	10.13	20.84	22.7	21.77
7.8	7.81	7.805	16.23	15.96	16.095
11.18	10.59	10.885	18.81	18.8	18.805

Age_HR	HS_Resting_HR	HS_HR_Base	HS_HR_5min	HS_HR_10min	HS_HR_15min	HS_HRmax	HS_HRavg	HS_RPE_MAX	HS_RPE_AVG	HS_%HRR
19	90	98	121	133	132	159	133	15	13	38.74
19	62	87	125	133	119	151	120	13	11	41.73
18	80	87	127	130	137	155	141	13	12	50.00
19	89	104	159	132	134	166	137	13	12	42.86
19	102	117	167	172	172	172	170	13	12	68.69
18	92	101	137	163	152	185	143	15	13	46.36
19	64	74	93	147	141	167	129	17	15	47.45
20	75	84	149	138	154	158	128	18	15	42.40
19	97	110	123	141	133	145	130	15	12	31.73
18	89	107	133	141	141	157	137	15	14	42.48
25	97	102	163	187	182	206	174	19	17	78.57
21	92	109	164	186	188	189	170	16	14	72.90
20	79	89	141	160	152	166	138	17	12	48.76
21	54	79	85	78	79	95	79	14	13	17.24
22	71	70	86	121	135	136	109	15	13	29.92
20	81	92	122	123	134	164	136	17	15	46.22
23	81	85	115	117	131	154	125	15	13	37.93
24	73	77	114	114	124	128	107	15	13	27.64
21	77	90	119	123	119	142	117	14	12	32.79
20	69	81	129	125	123	151	123	15	13	41.22
20	67	80	116	85	106	128	102	14	12	26.32
28	55	73	117	112	10	129	110	16	13	40.15
24	69	70	117	110	89	130	108	14	12	30.71
25	65	101	131	135	157	158	131	16	13	50.77
30	83	100	119	152	143	157	133	17	15	46.73

22	55	71	100	117	76	121	110	17	14	38.46
20	80	95	127	125	126	149	127	15	13	39.17
28	52	59	130	104	136	136	124	14	13	51.43
25	87	105	126	143	134	146	116	14	13	26.85
19	62	79	126	115	127	143	117	17	15	39.57
21	98	113	157	157	160	172	151	15	13	52.48
23	81	88	113	145	136	153	125	19	15	37.93
23	59	71	114	118	110	126	100	14	11	29.71
24	77	72	144	120	131	161	122	17	16	37.82
21	87	92	127	111	111	134	116	18	15	25.89
22	68	73	103	106	106	126	103	18	14	26.92

HS_VAS	HS*PACES_Enjoy	HS_PACES_Like	HS_PACES_Fun	HS_PACES_Good	HS*PACES_Frustrated	HS_PACES_total
8	6	6	6	7	7	32
2	4	4	2	5	4	19
4.7	5	4	3	5	5	22
0.2	1	1	2	6	4	14
4.3	4	4	4	4	4	20
2.8	3	3	3	3	2	14
6.2	6	6	5	3	6	26
1.9	4	3	1	6	5	19
7	6	5	4	6	7	28
6.2	6	4	5	6	6	27
0.4	4	4	2	5	4	19
3.2	3	3	4	3	4	17
6.9	5	5	4	5	5	24
7.5	7	7	6	6	7	33
7.9	7	7	6	7	7	34
2.9	3	5	4	3	6	21
6.2	5	4	4	5	4	22
5.3	6	6	4	5	7	28
7.1	7	7	7	7	7	35
2.2	3	2	2	4	4	15
3.9	4	4	1	7	4	20
5	5	4	3	6	5	23
10	7	7	7	7	7	35
4.8	5	3	3	6	4	21
5.3	4	4	4	5	5	22
5.8	6	6	6	6	6	30

1.2	4	3	2	7	4	20
0	2	1	1	4	2	10
2.9	3	2	3	4	4	16
6.3	6	6	5	6	7	30
2.9	4	3	3	4	6	20
5.1	4	4	4	2	4	18
3.7	5	5	4	5	6	25
4.9	5	4	4	6	6	25
6.1	4	5	5	6	6	26
0.7	2	2	2	5	3	14

HS_ACTG_WRIST_%Sed	HS_ACTG_WRIST_%Light	HS_ACTG_WRIST_%Mod	HS_ACTG_WRIST_%Vig	HS_ACTG_WRIST_%MVPA
8.45	15.75	39.82	28.43	75.8
34.57	34.19	25.61	2.56	31.24
31.5	27.02	26.5	11.65	41.49
11.53	21.88	38.76	17.12	66.59
52.11	35.98	10.24	1.02	0.64
78.23	18.18	3.07	0.26	3.59
9.48	14.85	20.23	34.57	75.67
19.72	26.76	48.27	4.23	53.52
34.31	43.41	20.36	1.41	22.28
19.21	14.72	39.56	25.74	66.07
12.16	29.58	46.99	8.45	58.26
26.89	43.02	27.53	1.02	30.09
48.14	30.22	18.82	2.05	21.64
44.56	35.08	19.97	0.26	20.36
12.8	58.64	27.02	1.15	28.55
9.86	23.56	37.77	14.08	66.58
36.11	36.62	20.36	3.33	27.27
12.16	35.08	51.73	0.9	52.75
24.07	19.08	28.55	15.11	56.85
22.92	14.98	32.52	20.61	62.1
17.03	21.25	39.82	17.03	61.72
18.18	22.02	48.27	9.86	59.8
25.22	32.91	36.11	5.38	41.87
9.48	27.27	49.42	13.44	63.25
27.02	25.99	39.56	5.25	46.99

27.02	29.71	32.01	8.45	43.28
62.36	33.03	3.59	0.51	4.61
11.27	34.69	45.45	6.27	53.78
20.23	25.99	40.59	9.73	53.78
20.36	28.81	36.88	8.96	50.83
22.66	36.36	31.63	6.91	40.97
22.66	34.96	27.02	9.6	42.38
20.61	31.37	27.53	11.01	48.02
37.26	35.31	25.74	1.15	27.4
36.62	37	23.18	2.3	26.38
16.65	32.14	36.36	10.5	51.22

HS_ACTG_WAIST_%Sed	HS_ACTG_WAIST_%Light	HS_ACTG_WAIST_%Mod	HS_ACTG_WAIST_%Vig	HS_WAIST_%MVPA
21.51	13.06	45.33	19.85	65.43
69.78	19.97	6.66	3.59	10.24
41.49	37.13	21.25	0.13	21.38
33.93	21.77	41.1	3.07	44.3
11.91	48.99	22	0	29.01
52.11	19.97	26.89	1.02	27.91
7.55	14.72	76.44	1.28	77.72
28.81	34.57	35.08	1.54	36.62
39.31	32.65	28.04	0	28.04
31.75	46.66	24.58	0	24.58
31.88	17.16	43.53	5.63	50.96
25.22	60.82	13.96	0	13.96
46.99	39.69	12.68	0.64	13.32
34.92	42.11	22.98	0	22.98
8.07	25.48	64.28	2.18	66.45
29.96	62.87	7.17	0	7.17
35.08	13.57	0.38	0	13.96
13.44	64.53	21.77	0.26	22.02
50.32	25.61	21.64	2.18	24.07
28.04	11.01	32.65	27.4	60.95
25.22	19.08	50.83	4.74	55.7
26.38	14.47	47.5	11.01	59.15
30.09	26.38	38.54	3.97	43.53
7.17	20.36	72.34	0.13	72.47
42.51	37.13	20.36	0	20.36
39.56	20.61	38.67	0.77	39.82

56.59	40.97	2.43	0	2.43
23.18	29.32	42.64	3.84	47.5
39.44	45.71	14.6	0.26	14.85
31.5	21	46.48	1.02	47.5
40.72	26.38	27.27	5.63	32.91
46.73	25.1	24.97	2.43	28.17
54.16	21.25	23.05	1.02	24.58
31.63	20.49	47.89	0	47.89
46.73	20.87	30.35	2.05	32.39
40.2	35.85	22.92	0.77	23.94

HS_ACTG_THIGH_%Sed	HS_ACTG_THIGH_%Light	HS_ACTG_THIGH_%Mod	HS_ACTG_THIGH_%Vig	HS_ACTG_THIGH_%MVPA
67.99	23.32	2.43	0.13	2.69
57.49	29.07	13.44	0	13.44
39.56	37.39	23.05	0	23.05
37.26	37.52	24.46	0.77	25.22
49.3	18.82	30.86	1.02	31.88
55.19	28.81	16.01	0	16.01
8.07	35.98	55.83	0.13	55.95
26.5	25.61	45.2	2.69	47.89
65.43	34.19	0.38	0	0.38
61.72	34.83	3.46	0	3.46
28.81	31.11	29.45	10.24	40.08
34.19	61.2	4.61	0	4.61
45.45	20.1	31.75	2.69	34.44
45.07	39.18	15.75	0	15.75
6.4	23.94	68.12	1.54	69.65
42.38	52.11	5.51	0	5.51
65.43	32.78	1.79	0	1.79
22.41	69.27	8.32	0	8.32
35.6	26.25	37.77	0.38	38.16
48.4	45.58	6.02	0	6.02
27.14	35.98	27.66	9.22	36.88
22.41	17.67	42.13	16.52	59.92
11.14	55.19	33.42	0.26	33.67
39.56	11.91	30.22	17.67	48.53

39.31	26.38	29.07	5.25	34.31
61.46	30.09	8.45	0	8.45
42.64	22.28	25.22	8.07	35.08
68.12	31.11	0.77	0	0.77
32.65	31.88	34.06	1.15	35.47
39.95	31.63	22.41	6.02	28.43
42.13	22.41	26.25	9.22	35.47
48.91	17.03	21.38	11.91	34.06
34.83	12.18	45.71	1.28	46.99
44.56	11.78	36.24	7.43	43.66
27.4	33.55	38.16	0.9	39.05

Relax Walk VR Data

RW_SBP1	RW_DBP1	RW_SBP2	RW_DBP2	RW_Arise	RW_Meal	RW_Caffeine	RW_Vig_Ex	RW_Meds	RW_Health_stat	RW_Smoke
134	92	136	92	330	0	0	0	0	0	0
118	77	116	72	375	0	0	0	0	0	0
120	73	113	64	315	0	0	0	0	0	0
146	90	136	78	120	0	0	0	0	0	0
107	67	105	65	615	0	0	0	0	0	0
127	93	130	94	435	0	0	0	0	0	0
129	58	121	60	510	0	0	0	0	0	0
134	65	137	58	375	0	0	0	0	0	0
114	72	101	71	270	0	0	0	0	0	0
109	74	104	73	360	0	0	0	0	0	0
130	68	139	69	150	0	0	0	0	0	0
118	81	111	75	30	0	0	0	0	0	0
118	65	116	65	330	0	0	0	0	0	0
116	75	117	73	60	0	0	0	0	0	0
114	64	111	63	60	0	0	0	0	0	0
140	99	144	87	60	0	0	0	0	0	0
150	85	150	91	360	0	0	0	0	0	0
129	71	121	69	585	0	0	0	0	0	0
105	66	102	68	120	0	0	0	1	0	0
115	82	116	77	270	0	0	0	0	0	0
120	72	115	79	120	0	0	0	0	0	0
133	82	141	72	630	0	0	0	0	0	0

158	69	149	63	150	0	0	0	0	0	0
118	76	119	77	60	0	0	0	0	0	0
114	76	115	72	105	0	0	0	0	0	0
118	62	117	59	330	0	0	0	0	0	0
113	75	108	73	690	0	0	0	0	0	0
141	82	130	81	330	0	0	0	0	0	0
117	89	114	91	600	0	0	0	0	0	0
125	74	127	76	90	0	0	0	0	0	0
142	89	147	77	60	0	0	0	1	0	0
122	76	126	72	600	0	0	0	0	0	0
133	69	146	77	70	0	0	0	0	0	0
137	80	126	85	630	0	0	0	0	0	0
130	71	122	69	300	0	0	0	0	0	0
146	61	133	60	270	0	0	0	1	0	0

RW_PPT_arm_Fam1	RW_PPT_arm_Fam2	RW_PPT_arm_Fam_AVG	RW_PPT_thigh_Fam1	RW_PPT_thigh_Fam2	RW_PPT_thigh_Fam_AVG
4.07	4.6	4.335	6.55	5.78	6.165
5.61	6.24	5.925	8	7.61	7.805
3.91	3.9	3.905	6.05	5.73	5.89
14.28	14.22	14.25	23.62	24.4	24.01
8.58	8.17	8.375	12.96	15.27	14.115
5.62	5.35	5.485	6.55	6.7	6.625
5.59	4.31	4.95	7.21	7.86	7.535
9.04	8.7	8.87	10.89	9.51	10.2
7.44	7.61	7.525	9.01	10.36	9.685
4.75	4.35	4.55	8.48	8.16	8.32
8.53	9.59	9.06	15.19	14.65	14.92
10.88	9.5	10.19	14.67	13.18	13.925
2.67	2.42	2.545	4.83	5.21	5.02
7.14	5.47	6.305	10.61	8.71	9.66
15.06	13.59	14.325	26.6	24.53	25.565
4.88	4.2	4.54	5.74	4.75	5.245
2.37	2.26	2.315	3.56	4.04	3.8
17.41	18.51	17.96	19.33	21.73	20.53
5.44	5.38	5.41	9.71	7.46	8.585
4.8	4.64	4.72	5.85	5.83	5.84
6.32	5.56	5.94	6.69	6.34	6.515
10.37	10.87	10.62	18.09	16.44	17.265
27.13	27.62	27.375	33.85	35.92	34.885
10.72	10.33	10.525	19.02	15.09	17.055
4.34	4.01	4.175	5.83	5.93	5.88

4.43	4.15	4.29	5.8	6	5.9
4.01	3.45	3.73	5.45	5.16	5.305
50.74	48.96	49.85	45.69	47.33	46.51
4.49	4.11	4.3	6.96	6.66	6.81
14.68	18.51	16.595	21.72	21.9	21.81
16.75	15.27	16.01	18.65	20.03	19.34
6.72	6.55	6.635	10.47	10.61	10.54
11.58	10.96	11.27	16.92	17.58	17.25
11.95	11	11.475	19.63	17.1	18.365
12.21	9.49	10.85	16.28	14.23	15.255
7.69	6.81	7.25	15.42	14.76	15.09

RW_PPT-PreVR1_arm	RW_PPT-PreVR2_arm	RW_PPT_PreVR_arm_AVG	RW_PPT-PreVR1_thigh	RW_PPT-PreVR2_thigh	RW_PPT_PreVR_thigh_AVG
5.5	5.39	5.445	7.02	6.53	6.775
5.59	4.91	5.25	7.03	7.87	7.45
3.57	3.94	3.755	5.48	5.3	5.39
17.86	16.44	17.15	24.25	27.96	26.105
9.5	8.75	9.125	12.18	11.97	12.075
5.41	4.92	5.165	6.21	6.97	6.59
5.77	5.36	5.565	7.47	7.83	7.65
8.29	6.56	7.425	9.28	9.07	9.175
9.01	8.23	8.62	12.35	12.38	12.365
4.19	4.1	4.145	6.78	8.48	7.63
9.92	10.37	10.145	13.55	15.63	14.59
8.53	7.46	7.995	11.97	11.24	11.605
2.14	2.34	2.24	4.45	3.61	4.03
5.81	5.81	5.81	12.6	11.35	11.975
13.82	14.66	14.24	26.14	24.63	25.385
4.51	4.29	4.4	5.65	7.9	6.775
3.12	3.54	3.33	4.16	4.59	4.375
15.75	18.04	16.895	24.41	21.41	22.91
7.83	5.68	6.755	7.8	9.93	8.865
4.64	5.91	5.275	5.71	5.66	5.685
6.34	6.28	6.31	9.82	8.34	9.08
7.63	7.89	7.76	13.62	16.23	14.925
26.22	28.93	27.575	38.4	35.55	36.975
11.6	10.86	11.23	17.11	15.88	16.495
3.58	3.24	3.41	5.78	5.73	5.755

4.52	4.15	4.335	6.18	5.99	6.085
3.92	4.24	4.08	5.17	5	5.085
35.32	49.75	42.535	47.29	53.15	50.22
3.07	4.16	3.615	6.6	6.71	6.655
14.34	17.75	16.045	22.65	21.93	22.29
13.7	19	16.35	18.48	18.92	18.7
7.47	7.27	7.37	10.1	11.31	10.705
10.25	9.85	10.05	16.71	14.25	15.48
9.34	9.84	9.59	18.75	19.03	18.89
14.02	11.3	12.66	13.79	18.59	16.19
9.45	8.19	8.82	16.55	15.76	16.155

RW_PPT-PostVR1_arm	RW_PPT-PostVR2_arm	RW_PPT_PostVR_arm_AVG	RW_PPT-PostVR1_thigh	RW_PPT-PostVR2_thigh	RW_PPT_PostVR_thigh_AVG
6.95	6.24	6.595	8.26	8.3	8.28
4.41	5.29	4.85	6.31	7.64	6.975
3.44	3.96	3.7	6.67	5.59	6.13
15.33	13.59	14.46	26.74	29.32	28.03
9.09	7.82	8.455	12.75	12.12	12.435
5.24	6.37	5.805	6.83	7.06	6.945
5.67	5.45	5.56	7.71	8.6	8.155
6.62	6.35	6.485	8.7	10.28	9.49
8.14	8.18	8.16	10.52	11.56	11.04
5.15	5.15	5.15	7.56	8.01	7.785
8.67	9.95	9.31	14.09	17.28	15.685
10.26	8.82	9.54	13.07	10.98	12.025
2.31	2.45	2.38	3.33	3.38	3.355
5.48	5.99	5.735	14.3	14.2	14.25
12.95	13.26	13.105	25.66	28.24	26.95
4.09	3.89	3.99	5.97	5.65	5.81
3.53	3.58	3.555	4.25	4.49	4.37
16.51	17.63	17.07	25.72	30.7	28.21
4.97	5.63	5.3	10.18	8.66	9.42
4.36	4.08	4.22	5.52	5.97	5.745
5.48	5.51	5.495	9.9	9.35	9.625
9.45	8.05	8.75	13.85	14.2	14.025
30.33	32.28	31.305	42.03	42	42.015
11.49	12.02	11.755	19.86	19.9	19.88
3.13	3.29	3.21	6.41	7.1	6.755

5.19	4.19	4.69	6.34	6.36	6.35
5.41	5.63	5.52	8.22	6.62	7.42
46.34	53.73	50.035	58.44	58.16	58.3
3.51	3.75	3.63	5.74	6.86	6.3
14.66	16.35	15.505	22.98	24.29	23.635
20.72	20.48	20.6	24.44	28.26	26.35
6.44	6.42	6.43	9.84	9.19	9.515
12.12	11.85	11.985	15.4	15.83	15.615
12.43	13.27	12.85	21.08	20.35	20.715
10.22	10.14	10.18	14.65	15.17	14.91
8.74	9.02	8.88	17.27	16.82	17.045

Age_HR	RW_Resting_HR	RW_HR_Base	RW_HR_5min	RW_HR_10min	RW_HR_15min	RW_HRmax	RW_HRavg	RW_RPE_MAX	RW_RPE_AVG	RW_%HRR
19	99	98	101	103	102	117	102	11	9	2.94
19	63	75	84	80	89	97	82	8	6	13.77
18	74	74	81	88	77	91	81	6	6	5.47
19	80	92	87	85	87	102	85	7	7	4.13
19	95	104	113	123	118	142	117	7	6	20.75
18	95	88	92	99	107	112	99	8	7	3.74
19	68	67	69	68	70	79	70	9	9	1.50
20	70	74	77	81	78	94	78	8	7	6.15
19	105	103	100	110	119	119	104	8	7	-1.04
18	81	93	105	95	114	118	102	9	9	17.36
25	93	90	96	102	91	106	93	9	8	0.00
21	99	105	110	108	109	124	112	6	6	13.00
20	74	92	116	113	116	130	111	9	9	29.37
21	54	62	65	68	72	78	67	6	6	8.97
22	57	59	64	60	65	74	62	8	6	3.55
20	91	103	100	94	105	109	98	7	6	6.42
23	82	95	95	100	97	105	95	6	6	11.30
24	60	59	59	58	60	68	60	6	6	0.00
21	75	74	81	81	81	93	82	6	6	5.65
20	78	97	95	106	102	110	98	7	6	16.39
20	75	78	76	83	77	92	79	6	6	3.20
28	59	61	65	69	66	76	67	6	6	6.02
24	73	75	77	78	82	85	76	6	6	2.44
25	74	79	90	92	98	104	91	7	7	14.05
30	76	81	94	102	102	112	97	7	7	18.42

22	70	73	80	78	79	95	79	8	8	7.03
20	84	95	105	103	101	116	103	7	6	16.38
28	53	65	74	66	70	77	66	6	6	9.35
25	70	89	92	91	99	105	91	6	6	16.80
19	63	72	77	85	76	99	79	6	6	11.59
21	99	102	103	102	97	111	99	7	7	0.00
23	94	97	92	98	95	109	94	6	6	0.00
23	64	69	76	68	79	82	71	6	6	5.26
24	70	73	79	77	86	87	78	7	7	6.35
21	75	72	79	72	76	86	76	6	6	0.81
22	72	72	70	70	76	79	72	6	6	0.00

RW_VAS	RW*PACES_Enjoy	RW_PACES_Like	RW_PACES_Fun	RW_PACES_Good	RW*PACES_Frustrated	RW_PACES_total
6.3	5	6	6	7	7	31
2.3	3	2	2	4	7	18
2.1	2	2	2	7	6	19
1.3	4	4	3	4	7	22
3.3	4	4	4	4	4	20
1.9	4	4	2	4	7	21
4.8	6	5	4	6	7	28
2.5	5	3	2	7	7	24
5.8	6	6	4	7	7	30
8.5	7	7	5	7	7	33
1.6	5	5	4	7	6	27
1.9	3	3	4	4	6	20
3.9	4	3	4	4	5	20
7.3	7	6	6	7	7	33
3.3	5	2	2	4	6	19
7.2	5	5	4	6	6	26
5.8	6	6	5	6	6	29
0.7	3	2	2	6	7	20
3.4	5	5	3	4	7	24
5	5	4	4	7	6	26
5.2	4	7	4	7	7	29
7.7	3	5	5	6	5	24
0	2	2	2	2	7	15
5.6	5	5	3	6	7	26
6.4	5	4	4	6	4	23
7.1	6	6	5	6	6	29

4.6	5	5	1	7	7	25
2.2	3	3	2	4	3	15
4.6	5	5	4	4	7	25
2.3	5	5	3	5	7	25
8	7	6	4	7	7	31
1.1	2	1	2	4	4	13
1.5	5	5	4	4	6	24
8.8	6	6	6	6	7	31
1.3	6	4	2	6	7	25
4.5	5	4	3	5	7	24

RW_ACTG_WRIST_%Sed	RW_ACTG_WRIST_%Light	RW_ACTG_WRIST_%Mod	RW_ACTG_WRIST_%Vig	RW_ACTG_WRIST_%MVPA
54.55	28.17	11.78	2.94	17.29
99.74	0.26	0	0	0
100	0	0	0	0
83.87	5.38	6.15	2.56	10.76
91.55	2.43	3.2	1.41	6.02
97.82	2.18	0	0	0
96.67	1.28	1.54	0.26	2.05
96.41	2.3	0.77	0.26	1.28
95.12	1.07	1.78	1.19	3.8
99.23	0.77	0	0	0
99.1	0.13	0.51	0.13	0.77
92.32	4.99	2.18	0.51	2.69
99.23	0.77	0	0	0
100	0	0	0	0
99.36	0.64	0	0	0
95.65	1.92	1.41	0.77	2.43
100	0	0	0	0
98.59	0.64	0.51	0.26	0.77
96.41	1.15	1.15	0.38	2.43
86.56	5.89	5.12	1.02	7.55
98.59	0.77	0.38	0.13	0.64
94.24	4.99	0.51	0.26	0.77
100	0	0	0	0
93.6	2.82	1.79	0.9	3.59
83.99	11.92	3.59	0.38	4.1

96.67	1.54	1.41	0.38	1.79
100	0	0	0	0
93.21	3.71	1.54	0.51	3.07
50.32	22.79	19.85	5.63	26.89
97.95	1.54	0.51	0	0.51
99.87	0.13	0	0	0
95.01	3.97	0.77	0	1.02
38.41	26.89	25.22	7.55	37.7
100	0	0	0	0
99.62	0.13	0	0.26	0.26
100	0	0	0	0

RW_ACTG_WAIST_%Sed	RW_ACTG_WAIST_%Light	RW_ACTG_WAIST_%Mod	RW_ACTG_WAIST_%Vig	RW_ACTG_WAIST_%MVPA
72.09	24.71	2.18	0.38	3.2
100	0	0	0	0
100	0	0	0	0
99.62	0.38	0	0	0
96.67	1.15	2.18	0	2.18
99.62	0.38	0	0	0
100	0	0	0	0
99.62	0.38	0	0	0
99.86	0.14	0	0	0
99.87	0.13	0	0	0
100	0	0	0	0
99.62	0.38	0	0	0
100	0	0	0	0
100	0	0	0	0
100	0	0	0	0
99.49	0.51	0	0	0
100	0	0	0	0
99.87	0.13	0	0	0
100	0	0	0	0
96.54	2.56	0.64	0	0.9
99.36	0.38	0.13	0.13	0.26
100	0	0	0	0
100	0	0	0	0
99.87	0.13	0	0	0
100	0	0	0	0

100	0	0	0	0
100	0	0	0	0
99.74	0.26	0	0	0
100	0	0	0	0
100	0	0	0	0
100	0	0	0	0
99.62	0.38	0	0	0
100	0	0	0	0
100	0	0	0	0
99.62	0.26	0.13	0	0.13
99.49	0.51	0	0	0

RW_ACTG_THIGH_%Sed	RW_ACTG_THIGH_%Light	RW_ACTG_THIGH_%Mod	RW_ACTG_THIGH_%Vig	RW_ACTG_THIGH_%MVPA
74.26	22.15	3.59	0	3.59
100	0	0	0	0
100	0	0	0	0
100	0	0	0	0
96.67	0.77	1.54	1.02	2.56
100	0	0	0	0
100	0	0	0	0
100	0	0	0	0
99.87	0.13	0	0	0
99.87	0.13	0	0	0
100	0	0	0	0
98.34	0.38	0.64	0.51	1.28
100	0	0	0	0
100	0	0	0	0
100	0	0	0	0
99.49	0.38	0.13	0	0.13
100	0	0	0	0
98.98	1.02	0	0	0
99.87	0.13	0	0	0
97.31	1.66	0.38	0.26	1.02
99.49	0.51	0	0	0
100	0	0	0	0
100	0	0	0	0
99.74	0.26	0	0	0
100	0	0	0	0

99.23	0.77	0	0	0
99.87	0.13	0	0	0
100	0	0	0	0
100	0	0	0	0
100	0	0	0	0
99.87	0.13	0	0	0
99.74	0.26	0	0	0
100	0	0	0	0
100	0	0	0	0
100	0	0	0	0
100	0	0	0	0

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CURRICULUM VITAE

Eric Joseph Evans

EDUCATION

GRADUATE

Indiana University at Indiana University – Purdue University Indianapolis (IUPUI)	Doctor of Philosophy in Health and Rehabilitation Sciences	December 2020
Indiana University at Indiana University – Purdue University Indianapolis (IUPUI)	Master of Science in Kinesiology Clinical Exercise Science Track	May 2016

UNDERGRADUATE

Indiana University at Indiana University – Purdue University Indianapolis (IUPUI)	Bachelor of Science in Kinesiology	August 2014

APPOINTMENTS

ACADEMIC

Indiana University – IUPUI School of Health and Human Sciences Department of Kinesiology	Teaching Assistant	08/2019 - Present 08/2014 – 5/2016
Indiana University – IUPUI School of Health and Human Sciences Department of Kinesiology	Research Assistant	05/2017 - Present 08/2014 – 05/2016

PROFESSIONAL DEVELOPMENT

Games for Health Journal — October 2019 - Present
Early Career Committee
Member

National Strength and Conditioning Association
July 2019
Annual Conference, Washington D.C.

American College of Sports Medicine
November 2018
Midwest Conference, Grand Rapids, MI

AWARDS AND HONORS

American Kinesiology Association
Spring 2016
Master's Scholar Award

IUPUI Graduate School
Fall 2019
Elite 50 Award (Nominated)

RESEARCH ACTIVITY

TITLE	FUNDING SOURCE	ROLE	DATES
Dissertation Project: The Effects of Virtual Reality on Physical Activity and Pain Sensitivity	N/A	PI	01/2019 - Present
Active Gaming: It's not just for young people	Center of Research and Learning	Co-PI	01/2015 – 06/2019
Reducing Sedentary Time in Fibromyalgia (ReSet-FM): A Feasibility Study	IUPUI PETM Faculty Research Opportunity Grant (FROG)	Graduate Research Assistant	04/2017 - Present
Role of deficient pain modulatory systems in chronic post-traumatic headache after mild traumatic brain injury	Indiana State Department of Health	Graduate Research Assistant	04/2018 – Present

PUBLICATIONS

Evans, Eric J., Naugle, Keith E., Owen, Tyler., & Naugle, Kelly M.., (2020). "Active Gaming: It Is Not Just for Young People". *Journal of Aging and Physical Activity*. Advance online publication. 10.1123/japa.2019-0303

RESEARCH PRESENTATIONS

Evans, E. *Reducing Sedentary Time in Fibromyalgia (ReSet-FM: A Feasibility Study.* Accepted abstract at American College of Sports Medicine Annual Conference (Virtual), San Francisco, CA., May 28th, 2020. Board #250.

Owen, T., **Evans, E.**, Crisler, M., Naugle, KM., Naugle, KE. *Comparing physical activity levels between age groups during active gaming.* Poster presentation at National Strength and Conditioning National Conference, Washington D.C., July 13th, 2019. Poster #45

Evans, E., Owen, T., Naugle, KE, Naugle, KM. *Active Gaming: It's not just for young people.* Poster presentation at National Strength and Conditioning National Conference, Washington D.C., July 13th, 2019. Poster #46.

Aqeel, D., **Evans, E.**, Keith, N., Bair., Naugle, KM. *A qualitative analysis to understanding participation in physical activity and sedentary behaviors in veterans with fibromyalgia.* Poster presentation for IUPUI Research Day, April 12, 2019.

Owen T, **Evans E**, Naugle KM, Naugle KE. *Efficacy of active gaming in exercise prescription.* Poster presentation for IUPUI Summer Symposium, Indianapolis, IN, July 26 2018

Evans, E., Owen, T., Cavanaugh, R., Naugle, K.E., Naugle, K.M. Measuring the Effect of Active Video Games on Aerobic Outcomes and Enjoyment in Young Health Adults. Poster for IUPUI Research Day, April 6, 2018.

Evans, E., Streepey, J., Bahamonde, R. Validity of iPhone Apps to Measure Knee Range of Motion in Clinical Settings. Poster for IUPUI Research Day, April 17, 2015

TEACHING ACTIVITY

Course #	Short Title	Format	Role	Term	Enrollment
K212	Introduction to Exercise Science	Lecture	Teaching Assistant	Spring 2020	67
K212	Introduction to Exercise Science	Lecture	Teaching Assistant	Fall 2019	140
P205	Structural Kinesiology	Laboratory	Lab Instructor	Spring 2016	50
P212	Introduction to Exercise Science	Lecture	Teaching Assistant	Spring 2016	98
P443	Internship: Physical Education	Internship	Teaching Assistant	Summer 2015	20
P419	Fitness Testing and Interpretation	Laboratory	Lab Instructor	Summer 2015	24
E100	Experience in Physical Activity	Lecture	Instructor	Summer 2015	5
P215	Principles & Practices of Exercise Science	Laboratory	Lab Instructor	Summer 2015	16
P212	Introduction to Exercise Science	Online	Teaching Assistant	Summer 2016	18
P205	Structural Kinesiology	Laboratory	Lab Instructor	Spring 2015	50
P212	Introduction to Exercise Science	Lecture	Teaching Assistant	Fall 2014	204
P205	Structural Kinesiology	Laboratory	Lab Instructor	Fall 2014	53