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Assessing the physiological cost of active video games (Xbox Kinect™) versus sedentary video games in young healthy males

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Key Words: Energy expenditure; gaming; physical activity; exergaming.

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Abstract

Objectives: The aims of this study were twofold; 1) to compare the physiological costs of AVGs and SVGs and 2) to compare the exercise intensities attained during AVGs to the exercise intensity criteria for moderate and vigorous physical activity, as stated in current physical activity recommendations for improving public health.

Materials and Methods: 19 young males participated in the study (age: 23 ± 3 years, height: 178 ± 6 cm, weight: 78 ± 15 kg). Participants completed a $\dot{V}O_{2max}$ test and a gaming session, including active video games (AVGs) (Reflex Ridge, River Rush and Boxing, Kinect™) and sedentary video games (SVGs) (FIFA 14 and Call of Duty). Heart rate (HR) and oxygen uptake ($\dot{V}O_2$) were recorded continuously during all video games. Rating of perceived exertion (RPE) was taken every 3 minutes during AVGs and SVGs. Energy expenditure, expressed as metabolic equivalents (METs), was calculated. One MET was defined as the volume of oxygen consumed at rest in a seated position and is equal to 3.5ml O_2 per kg body mass per minute. The exercise intensity for each game was expressed as a percentage of maximal oxygen uptake ($\%\dot{V}O_{2\,max}$) and percentage of age-predicted maximum HR ($\%HR_{max}$).

Results: Exercise intensity ($\%HR_{max}$ and $\%\dot{V}O_{2\,max,}$ RPE) and energy expenditure (METs) were significantly higher during active gaming compared to sedentary game play ($p < 0.01$). AVGs elicited moderate levels of exercise intensity (64-72 $\%HR_{max}$) in line with current recommended physical activity guidelines.

Conclusions: Our results indicate AVGs provoke physiological responses equivalent to a moderate intensity physical activity.

Key words: Energy expenditure; gaming; physical activity; exergaming.

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Introduction

Physical inactivity is the fourth most important risk factor for chronic, non-communicable disease accounting for 6%, 7% and 10% of the burden of disease for coronary heart disease, Type II diabetes and breast and colon cancers respectively [1-2]. Additionally, physical inactivity contributes to obesity [3], depression [4-5] and dementia [6]. Despite strong empirical evidence supporting the benefits of physical activity on a range of health outcomes, many young adults in the UK [7], and worldwide [8-9], do not meet minimum physical activity recommendations. Current physical activity guidelines [10-12] suggest adults should engage in at least 150 minutes, accumulated, moderate intensity physical activity per week with moderate intensity exercise ranging between 4.8-7.1 metabolic equivalents (METs) for young healthy males [12]. However, in today's society there is becoming an increase in sedentary behaviour which is referred to as sitting and lying activities that require low levels of energy expenditure (EE) [13-14] and have metabolic equivalent (METs) levels between 1 and 1.5 [15]. In particular seated video gaming can be classified as a sedentary behaviour [16]. It has been reported that in the UK, video games are played between 3-7 times per week, with each session lasting on average 1.9 hours by youth and adolescents aged 11-15 years old [17].In the Netherlands the results are slightly higher with 95% of young males aged between 11-19 years spend on average 10 hours of sedentary gaming per week [18]. Some authors suggest time spent playing sedentary video games replaces time otherwise spent in more health enhancing, active behaviours i.e. moderate and vigorous physical activity, contravening public health recommendations [19-20]. As such, specific concerns have arisen surrounding time spent -engaged in sedentary video game activity and the health of young people.

Historically, video gaming was predominantly a sedentary leisure activity. The player simply interacted with the game on a TV screen or computer via a handheld controller. More recently, active video games (AVGs), also known as "exergames", have emerged in an attempt to increase levels of physical activity and offer an alternative fun and enjoyable, home-based mode of exercise, accessible for all ages, whether as a means of leisure activity or for fitness gains [21]. AVGs integrate body movement (isolated limbs or whole body) into the game experience and video gaming. Movements are sensed via video cameras (Sony, Eye Toy™ and Microsoft, Xbox Kinect™) or weight-sensing

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platforms (Konami, Dance Dance Revolution™ and Nintendo Wii Fit™). Wii Fit™ (Nintendo, Ltd, Tokyo, Japan) primarily uses a balance board and handheld controller to move the avatars (computer representation of self), as opposed to the Xbox Kinect™ (Microsoft, Redmond, WA, USA) where a camera captures body movements in real-time without the need to use worn or handheld controllers.

Given the time individuals currently spend engaged in video-gaming, it may be argued, AVGs potentially offer a novel and exciting opportunity to reduce sedentary behaviours and increase levels of physical activity to meet current public health, physical activity recommendations across the full age span, if the minimum threshold volume (intensity x frequency x duration), for accrual of health benefits, is met. However, research evidence to support this argument is currently unavailable. Current physical activity guidelines recommend 150 min.wk^{-1} of at least moderate intensity activity, taken as bouts of 30-60 min (5 d.wk^{-1}) or 20-60 min (3 d.wk^{-1}). Each session may be continuous or accumulated over multiple sessions, each session a minimum of 10 min duration. Guidelines also suggest, if the above recommendations cannot be met fully, some activity is better than none. Table I outlines the criteria used to classify levels of physical activity based on exercise intensity. Few studies to date have measured the physiological cost of active video gaming, and outcomes are conflicting. Previous studies have assessed physiological responses to AVGs in children [22-25], adolescents [26] and older adults [27] using a range of AVGs such as, Nintendo Wii™ [23] and Dance Dance revolution (DDR)™ [28]. Preliminary results from these studies, indicate AVGs elicit "light" to "moderate" levels of physical activity and are more physiologically demanding compared to traditional SVGs in different groups: normal weight to obese children and adults [23]; young children [24]; healthy adolescents[26]; and older adults [27]. However, the early studies, which used the Nintendo Wii™ console, may be criticised for not imitating whole body movement and a restricted application to movement on a balance board for Wii Plus. Although promising, the variations in AVGs make the results inconclusive for any true generalisations to be made. Limited data is available for the young male adult population.

The recently developed Kinect™ AVGs requires hands free play and whole body movement. To our knowledge, only three studies to date have explored the physiological responses of Kinect™

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whole body movement AVGs [22,30,31]. O'Donovan *et al.* [30] compared the energy expenditure of Kinect™ Reflex Ridge to Wii™ Boxing in 14 adults (mean age 21 ± 3 years). Each game was played over a 10 minute period and, heart rate, metabolic equivalents (METs), oxygen consumption and kilocalories expended recorded. Results indicated that the Kinect™ Reflex Ridge AVG elicited significantly greater energy expenditure than the Wii™ Boxing [mean ± standard deviation (SD); 4.26 ±1.09 compared to 3.14 ±1.03 METs, $p<0.05$]. However, the difference in energy expenditure may be partially explained by the muscle volume recruited during each game; Reflex Ridge demands full body movement compared to the isolated upper body movements for Wii™ Boxing. The authors concluded neither system elicited the moderate intensity activity levels to meet minimum physical activity guidelines, which supports earlier findings ([23,26,27,28]). Mellecker and McManus [22] compared the effects of Kinect™ River Rush to Gamercize stepper and the Xavi X J-mat in 18 girls (8.5 ± 0.2 years). Results showed that the Kinect™ River Rush did not meet guidelines for moderate intensity exercise, however Gamercize and XaviX J-Mat did. The final study to assess physiological responses of AVGs compared to traditional gaming was by Smallwood and colleagues [31] who assessed 15 children (11-15 yrs) playing Dance Dance Revolution (DDR) and Kinect Sports (Boxing) compared to traditional seated gaming. Results showed that AVGs produced significantly greater energy expenditure ($p<0.05$) and that the Kinect sports (Boxing) elicited moderate levels of exercise intensity for children with a mean MET of 4.03, however DDR only produced light intensity exercise 2.91 METs. Although physiological cost of AVGs compared to traditional gaming has been compared in the past, there still appears to be large variations in results and methods. Comparisons between studies are further curtailed by the variations in games played, player age and experience, number and choice of games included per study (one only for Kinect studies) and duration of game play. No study has compared the physiological effects of multiple dynamic Kinect™ AVGs to SVGs.

Currently, sedentary activities, including SVGs, are a public health concern, which must be addressed especially in the young. The use of AVGs may be a potential solution to the problem. Research has suggested that AVGs is an enjoyable activity to perform [32] however evidence still lacks regarding the true exercise intensity of AVGs for young adults males in relation to public health

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guidelines. The aims of this study were twofold; 1) to compare the physiological costs of AVGs and SVGs and 2) to compare the exercise intensities attained during AVGs to the exercise intensity criteria for moderate and vigorous physical activity, as stated in current physical activity recommendations for improving public health.

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2. Materials and Methods

Ethical clearance was granted by the institutional Ethics Sub-Committee for Sport at the University Of Sunderland and adhered to the Declaration of Helsinki. A convenience sample of nineteen healthy male participants volunteered to take part in the study. Participants were recruited through University emails, social media and word of mouth. Participant characteristics are presented in table II. Prior to the study, participants were fully informed of protocol and procedures and written consent was obtained. Individuals were included in the study if they were physically active (3 or more moderate-vigorous physical activity sessions per week), free from injury and suitably healthy to complete a maximal aerobic exercise test. Exclusion criteria included those with an inability, or any doubt of ability, to give informed consent and/or to comprehend and write English and current, or history of any medical condition or injury which would contraindicate participation. All participants completed a self-report health screening questionnaire prior to participation. Having satisfied the inclusion criteria, participants attended the exercise physiology laboratory at the University of Sunderland on two separate testing sessions, each separated by at least 48 hours. In the first session, following familiarisation with the research team, equipment and protocols, participants completed resting measures and an incremental exercise test to volitional exhaustion on a treadmill. During the second session participants completed the sedentary and active gaming activities..

Stature (cm) and body mass (kg) were recorded using a wall mounted stadiometer (Seca,HAB Direct, UK) and digital balance scales (Seca flat scale 761, Northumbria Medical Supplies, UK) respectively. Body mass index was established from body mass and stature using the equation: body mass (kg) /stature squared (m^2). Participants relaxed quietly in a comfortable, supine position for 10 minutes to allow resting measures of heart rate (HR) and blood pressure (BP) to be recorded using a Polar RS800CX HR monitor (Polar Electro, Oy, Finland) and Omron BP monitor (Omron M10, Omron healthcare Co Ltd, Kyoto, Japan) respectively. Blood pressure was taken at resting as a health screening procedure. Screening was necessary to determine any pre-existing conditions. A resting HR

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> 100 b.min^{-1}, systolic BP > 140 mm Hg and/or a diastolic BP > 90 mm Hg were contraindications to exercise participation. The laboratory temperature was maintained between 20-24°C.

During exercise expired air was continuously analysed for oxygen (O_2) and carbon dioxide (CO_2) using a breath by breath online system (Metalyzer 3B®, Cortex, Biophysic, Leipzig, Germany). Minute ventilation ($\dot{V}_E$) and the volumes of oxygen consumed ($\dot{V}O_2$) and carbon dioxide produced ($\dot{V}CO_2$) were recorded. The respiratory exchange ratio (RER) was expressed as the ratio of $\dot{V}CO_2$ to $\dot{V}O_2$. Expiratory flow volume was measured using a digital volume transducer (Triple V® turbine). Prior to each test equipment was fully calibrated according to manufacturer instructions. Following a 60 minute warm up period, the electro-chemical O_2 cell and the CO_2 infra-red analyser in the Metalyzer 3B online system were calibrated against room air and a reference gas of known composition (5% CO_2, 15% O_2 and 80% N_2). Volume was established using 5 inspiratory and 5 expiratory strokes using a 3-L calibration syringe (Cortex, Biophysik, Leipzig, Germany). Participants were individually fitted with an appropriately sized oro-nasal face mask (Hans Rudolph, USA) with low dead space volumes.

Immediately prior to the continuous, incremental exercise test to volitional exhaustion, participants completed a 10 minute warm up at a self-selected pace on the treadmill (Woodway, USA). The initial running velocity for the maximal exercise test was set at 2.77 m.s^{-1} (10 km·h^{-1}). Treadmill velocity was increased by 0.28 m.s^{-1} (1 km·h^{-1}) every 3 minutes until volitional exhaustion. The treadmill gradient was maintained at 1% throughout the test [33]. HR and expired air were continuously recorded throughout the protocol and rate of perceived exertion (RPE), (Borg Scale 6-20[34]) noted in the final 10s of each stage. Perceived exertion was defined as how hard participants felt their body was working in general based on the physical sensations they may experience during the activity, including increases in HR, respiration, breathing rate, sweating, and muscle fatigue. The 15 point numerical scale is supported by verbal descriptors, where 6 is defined as “no exertion at all”, 11 “light”, 13 “somewhat hard”, 15 “hard (heavy)”, 17 “very hard” and 20 “maximum exertion”). RPE values between 12-13 and 14-17 equate to “moderate” and “vigorous” intensity exercise respectively (ACSM, 2011). Participants were verbally encouraged during the test. The test was considered a

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maximal effort if three of the following criteria were satisfied: HR within 10 beats of predicted HR_{max} calculated as 220 – age, a plateau in $\dot{V}O_2$ despite an increase in running velocity, a final RER >1.1 and an end-point RPE >19. On completion of the test, the treadmill velocity was immediately lowered to 1.39 $m \cdot s^{-1}$ (5 $km \cdot h^{-1}$) for an active cool-down to minimise the risk of blood pooling. Participants reported back to the laboratory on a second occasion to complete the SVGs and AVGs tests. A minimum rest period of 48 hours was scheduled between the first and second testing sessions. The multi-directional AVGs selected included Kinect™ Adventures™ (Reflex Ridge and River Rush) and Kinect Sports™ (Boxing). SVGs consisted of playing Xbox™ Call of Duty Black Ops and Xbox™ FIFA 2014. The order video games were completed was randomised for each participant. Details of each video game are summarised in table III. Each game was played for 15 minutes. HR and $\dot{V}O_2$ were continuously measured and RPE recorded every 3 minutes during game play and an average for the game was used for analysis. For each AVG and SVG a mean METs score was calculated from $\dot{V}O_2$ data using the formula: 1 MET =3.5 $ml.min^{-1}.kg^{-1}$ $\dot{V}O_2$ at rest. Computed values were compared to current physical activity recommendations (ACSM, 2011).

All data is presented as mean ± standard deviation (SD). Normality of data was confirmed using the Kolmogorov-Smirnov test. Mauchly test was used to determine sphericity. A one way ANOVA with repeated measures was selected to determine significant physiological differences between each AVG and SVG game mode (Reflex Ridge, River Rush, Boxing, Call of Duty, FIFA 2014). A Tukey post hoc test was used to identify individual differences between games. A Bonferroni correction was applied to limit type 1 error due to multiple paired testing. 95% confidence intervals (CI) are reported for significant data. The alpha level was set *a priori* at ≤ 0.05. Data analysis was conducted using the Statistical Package for Social Sciences version 21 (SPSS Inc., Chicago, IL, USA).

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3. Results

Descriptive data for the physiological responses observed during the individual AVGs and SVGs are presented in Table IV.

Cardiorespiratory responses (HR) during individual SVGs and AVGs was significantly higher than resting value, respectively ($p < 0.05$) (Table IV). Mean HR responses during the individual AVGs varied by 15 b·min^{-1} and were significantly higher than resting values ($p < 0.001$). Participants accomplished the highest HR (142 ± 18 b·min^{-1}), exercise intensity (72 ± 9% $\%HR_{max}$) and energy expenditure (10.8 ± 3.2 kcal·min^{-1}) playing Xbox Kinect™ Reflex Ridge followed by Xbox Kinect™ Boxing and Kinect™ Xbox River Rush (Table IV). A one-way analysis of variance with repeated measures revealed significant differences in HR between game modes (AVGs compared to SVGs), ($F = 9.92$, df =9, $p = 0.04$). Post hoc tests (with Bonferroni correction) identified differences between (1) Xbox Kinect™ Reflex Ridge and Xbox Kinect™ Call of Duty ($p < 0.01$), Xbox Kinect™ FIFA 2014 ($p < 0.01$) and Xbox Kinect™ River Rush ($p < 0.01$), (2) Xbox Kinect™ Boxing and Xbox Kinect™ Call of Duty ($p < 0.01$) and Xbox Kinect™ FIFA 2014 ($p < 0.01$) and (3) Xbox Kinect™ River Rush and Xbox Kinect™ Call of Duty ($p < 0.01$) and Xbox Kinect™ FIFA 2014 ($p < 0.01$). No significant differences were evident between Xbox Kinect™ Call of Duty and Xbox Kinect™ FIFA 2014 ($p = 0.17$) or Xbox Kinect™ River Rush and Xbox Kinect™ Boxing ($p = 0.124$).

Mean RPE for each AVG ranged between 'moderate' (11 ± 2 Xbox Kinect™ River Rush,) to 'somewhat hard' (13± 2, Xbox Kinect™ Reflex Ridge) and were significantly higher than the mean RPE reported for both individual SVGs (mean RPE 6 ± 1, 'no exertion at all' Xbox Kinect™ Call of Duty and Xbox Kinect™ FIFA 2014,).

Public Health Recommendations

The main findings from our study reveal AVGs were performed at a higher mean exercise intensity (68 ± 11 $\%HR_{max}$, 47.4 ± 12.5 $\%VO_{2max}$, 7 ± 2 METs and 12 ± 2 RPE) compared to SVGs (38.5 ± 6.5$\%HR_{max}$, 9.65 ± 2% VO_{2max}, 1 ± 0 METs, and 6 ± 1 RPE $p < 0.05$) and meet the "moderate"

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intensity exercise classification criteria (ACSM, 2011), whereas SVGs fall into the "very light" intensity category (Table IV). All participants were physically active in relation to current guidelines (ACSM, 2011) exercising to moderate intensity 3-5 times per week for at least 30 minutes.

For individual games during AVG, Reflex Ridge emerged as the most intense of all of the games (72 ± 9, %HR_{max}, 54.5 ± 13.6 %$\dot{V}O_{2max}$; 8± 2 METs; and RPE, 13 ±2). This represented the moderate intensity physical activity category for all variables, except for METs, which fell into the vigorous intensity category, using ACSM (2011) criteria for both the general population and the young adults population (20-39 yrs) respectively (See table I). Boxing was the next most intense game with data similar data to Reflex Ridge: moderate exercise intensity category for % HR_{max} (69 ± 12%), % $\dot{V}O_{2max}$ (54.4 ± 12.3%) and RPE (12 ±2 units); and vigorous intensity exercise for METs (7 ± 2). River Rush was the only AVG, which had variations between light and vigorous intensity exercise. Light intensity exercise was demonstrated for % $\dot{V}O_{2max}$ (41.4 ± 11.5%) and RPE (11± 2 units). Moderate intensity exercise was demonstrated for % HR_{max} (64 ± 11%) and METs fell between moderate (aged related) and vigorous (general population) at 6 ± 2. For both the SVGs, exercise intensity was deemed very light on all variables (See Table I)

4. Discussion

The aims of this study were (1) to explore the physiological responses of AVGs and SVGs in young healthy males and (2) compare exercise intensities attained during AVGs and SVGs to the exercise intensity criteria for moderate and vigorous physical activity stated in current physical activity recommendations for health gain. This was the first study to directly compare physiological responses of active and sedentary video gaming.

Exercise intensity data for AVGs and SVGs show that AVGs meet the current moderate, physical activity criteria for young healthy males[10-12] (Table IV) . Our data suggest SVGs elicit "low" intensity activity. Variations in exercise intensity were clearly observed between active and sedentary games

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and also between individual AVGs, but not between SVGs. Mean exercise intensity ranged between 64-72 %HR_{max} for individual Xbox Kinect™ AVGs, notably higher than mean exercise intensities reported in the research literature [29]. In our study, Xbox Kinect™ Reflex Ridge produced the highest mean HR and exercise intensity (142 ± 18 beats.min^{-1}, 8 ± 2 METs, 72 ± 9 % HR_{max}) and Call of Duty (CoD) was the SVG that produced the lowest exercise intensity (76 ± 13 beats.min^{-1}, 1 ± 0 METs, and 38 ± 7% HR_{max}) . Due to limited research evidence, few direct comparisons may be made between our findings and that of previous studies[22, 25, 29 30]. O' Donovan *et al*., [30] observed a mean exercise intensity of 4.26 ± 1.09 METs, in a sample of young adults (21 ± 3 yrs) playing Xbox Kinect™ Reflex Ridge, substantially lower than the results we present. In a group of 8 year old girls, Mellecker and McManus [22] concluded the Xbox Kinect™ River Rush AVG did not elicit moderate levels of energy expenditure. We found the Xbox Kinect™ River Rush AVG did induce an exercise intensity, which met the moderate physical activity criteria. A number of reasons may explain the outcome variations between studies. Differences may be attributed to the proportion of muscle mass recruited, understanding of the game, playing experience, motor skill acquisition, participant motivation, and frequency of movements during play, physiological monitoring equipment or laboratory conditions between studies. Variations between understanding the game and playing experience could particularly be contributors to variations in results. When playing on consoles such as the Nintendo Wii, previous game play and knowledge of the games would give participants and advantage over those with minimal playing experience, as they would understand what is required in the game, and also the cheats, for example more rapid wrist movements using the Wii control makes the avatar move faster resulting in greater game achievement.

O' Donovan and Hussy [29] reported a mean exercise intensity of 71% HR_{max} in young adults playing the Nintendo Wii Fit™ Jogging AVG and 58% HR_{max} (3.1 METs) for Nintendo Wii™ Boxing. Our data for Xbox Kinect™ Boxing is considerably higher at 69% HR_{max} (7 METs). A plausible explanation may be attributed to the whole body, multi-directional movements, enabled by the Xbox Kinect™ console, activating greater muscle mass recruitment, in contrast to the handheld controller used in Nintendo Wii™ Boxing. Similarly White *et al*., [25] found that Wii Sports™ classified

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"light activity" as <3 METs and running was the only one that produced moderate intensity exercise (5.6 ± 1.4 METs), however it should be noted that this was in a sample of young boys. The MET of running was similar to the levels we report in the current study for the Xbox Kinect™. Irrespective of game, METs ranged from 6-8 ± 2 METs showing moderate intensity exercise can be achieved using AVGs in particular the Xbox Kinect™.

Although our results are promising and this is, to the knowledge of the authors, the first study to compare the physiological costs of active video gaming using the Kinect™ and sedentary video game play, there are a number of important limitations to consider. The research was carried out in a controlled laboratory environment, whereas exergames are primarily designed for home based activity. Knowing they were being observed and their data recorded, participants may have expended more energy than may be exerted in the unobserved home environment. The sample size was small and researcher bias cannot be ruled out with a convenient sampling strategy. Generalization is restricted to the young, healthy, active male population. Given the promotion of exergaming as an alternative form of physical activity, further exploration of the physiological responses across a wider range of popular games would be beneficial. Future work should also consider exploring the physiological responses and energy expenditure in the home environment. Forde and Hussey [35] assessed how a group (n=820) of children played both SVGs and AVGs in the home environment. Results showed that 58% of them met physical activity guidelines for minimal exercise intensity. On average more children (68%) played SVGs compared to 55% playing AVGs. Although encouraging to observe in a large sample that a greater proportion of children are playing AVGs, SVGs are still being played for longer, and even those with access to AVGs, played them in a sedentary mode. Future directions for AVG is to encourage the use of consoles, which require movement, such as the Kinect, which cannot be played in a seated position. Finally, given the opportunity for multi-player games, the physiological cost of competitive, multi-player active game play, offers an exciting and novel avenue for research.

5. Conclusion

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Our findings support the promotion of active, but not sedentary, gaming as an acceptable, alternative mode of moderate intensity physical activity. Sedentary gaming should be restricted to avoid encroaching on valuable time otherwise spent in active health enhancing behaviours. Exergames are, for many, an enjoyable mode of home-based physical activity. Future research should focus on larger, adequately powered, population based, multi-centre collaborations to enhance the strength of evidence to promote exergaming as an accepted alternative from of physical activity.

6. Practical Implications

- Active video gaming using the Kinect™ offers a promising, alternative mode of moderate intensity physical activity for young healthy males (>6 METs and 64-76 $\%HR_{max}$).
- Variations in exercise intensity and energy expenditure exist between exergames. Games requiring full body movements in all planes of motion, elicit the greatest exercise intensity and energy expenditure.

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Author Disclosure Statement

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The article has not been previously published (except in abstract form) and is currently no under consideration form any other journal. There is no conflict of interest from any author(s) and there is no competing financial interests exist related to the research

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Table I Classification of exercise intensity: Adapted from the American College of Sports Medicine

Intensity	% HR max	% V02max	Rate of Perceived exhaustion (RPE)	Absolute intensity METS	Young (20-39 yr)
Very light	<57	<37	< very light (RPE <9)	<2	<2.4
Light	57-63	37-45	Very light- fairly light (RPE 9-11)	2.0-2.9	2.4-4.7
Moderate	64-76	46-63	Fairly light – somewhat hard (RPE 12 13)	3.0 – 5.9	4.8-7.1
Vigorous	77-95	64-90	Somewhat hard – very hard (RPE 14-17)	6.0-8.7	7.2-10.1
Near-maximal to maximal	>96	>91	> Very hard (>18)	>8.8	>10.2

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Table II Participants Characteristics

N=19	Mean ± SD	Range
Age (years)	23 ± 3	20 - 33
Height (cm)	178 ± 6	170 - 191
Weight (kg)	79 ± 15	59 - 104
Resting Heart Rate (beats·min^{-1})	73 ± 13	54 - 94
$\dot{V}O_{2\,max}$ (ml·kg^{-1}·min^{-1})	51 ± 10	26.2 - 66.7
Body Mass Index (Kg·m^{-2})	25 ± 4	19.1 - 35.1
Basic Metabolic Rate (kcal·m^{2}·h)	1878 ± 213	1580- 2251

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Table III Comparison of movements for AVGs and SVGs

Exergames	Instructions	Movements required
ACTIVE		
Reflex Ridge	Participants steer a cart along a track by moving their body from left to right and jumping up and down (taking off and landing on two legs). At the start of the game participants stand in a neutral standing position, with their arms raised straight in front of them as if they were grabbing onto bars. The aim of the game is to collect as many coins as possible in the time allotted: jumping over, or, squatting underneath barriers using the upper body to reach out in both medial and lateral directions depending on the position of the coins. They can move the body laterally to either the left or right to avoid barriers.	Full medial-lateral weight shifting. Vertical jumping and squatting low.
River Rush	Participants steer a river raft boat down the rapids collecting points by moving the body from left to right and jumping up and down (taking off and landing on two legs). At the start of the game participants stand in a neutral standing position, and jump up and land on two feet to start the game (see image 4). The aim of the game is to collect as many coins as possible in time allotted.	Full medial-lateral weight shifting of the centre of gravity over the base of support.
Boxing	Participants have to avoid punches to the head and stomach by moving the upper body and knock their virtual opponent out as fast as possible (see image 1). At the start of the game participants stands in a static upright position with both feet on the ground. They move the upper body (torso and arms) to block shots from the virtual opponent and attempt to strike their opponent in the head and torso by punching with either arm.	Full medial-lateral weight shifting of the centre of gravity over the base of support. Shoulder flexion and extension
SEDENTARY		
Call of duty	Participants control their character as long as possible against increasing waves of Zombies.	Sedentary (seated position throughout)
FIFA 14	Participants control their football team against a computer lead team.	Sedentary (seated position throughout)

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Table IV Physiological response to active exergames versus sedentary exergames

Game	Heart rate ($b \cdot min^{-1}$)	% HRmax ($b \cdot min^{-1}$)	$\dot{V}O_2$ ($ml.min^{-1}.kg^{-1}$)	% $\dot{V}O_2$max ($ml.min^{-1}.kg^{-1}$)	METs	RPE	$Kcal \cdot min^{-1}$
Resting	73 ± 13	36.8 ± 3	-	-	1 ± 0	6 ± 0	-
Active							
Reflex Ridge	142 ± 18*¥	72 ± 9 *¥	27.4 ± 6.7	54.5 ± 13.6 *¥	8 ± 2 *¥	13 ± 2 *¥	10.8 ±3.2
River Rush	127 + 22 *	64 + 11*	20.9 + 5.8	41.4 + 11.5 *	6 + 2*	11 + 2 *	8.2 +2.5
Boxing	136 ± 24 *	69 ± 12*	24.0 ± 5.6	46.4 ± 12.3 *	7 ± 2*	12 ± 2 *	9.3 ± 2.6
Mean ± SD	135 ± 21	68 ± 11×	24.1 ±6.0	47.4 ±12. 5×	7 ± 2×	12 ± 2×	9.4 ±2.7
Sedentary							
Call of Duty	76 ± 13	38 ± 7	4.6 ± 1.0	9.3 ± 2.0	1 ± 0	6 ± 1	2.0 ±0.4
FIFA 14	77 ± 12	39 ± 6	5.1 ± 1.0	10.0 ± 2.0	1 ± 0	6 ± 1	1.8 ±0.3
Mean ± SD	76.5 ± 12.5	38.5 ± 6.5ᵛ	4.8 ± 1.0	9.65 ± 2.0 ᵛ	1 ± 0 ᵛ	6 ± 1 ᵛ	1.9 ± 0.35

*Significantly different from sedentary games ($p \leq 0.01$): Call of Duty and FIFA 2014
¥ Significantly different from River Rush ($p<0.01$)
× Indicated moderate intensity exercise for AVGs in accordance with ACSM guideline,
ᵛ Indicates light activity for SVGs in accordance with ACSM guidelines.

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Assessing the physiological cost of active video games (Xbox Kinect™) versus sedentary video games in young healthy males

The author (s) would like to thank the reviewers and Games for Health Journal the opportunity to re-submit the article for publication and to thank the reviewers for their valuable comments to which the author (s) believe the manuscript has been strengthened.

Reviews comments	Changes
Keywords	Amended on L.19 to the same as L.46
Abstract	L.34 changed to "Rating of perceived exertion (RPE) was taken every 3 minutes during AVGs and SVGs" same as L.198 L.26 aims are consistent with L.130 The aims of this study were twofold; 1) to assess and compare the physiological costs of AVGs and SVGs and 2) to compare the exercise intensities attained during AVGs to the exercise intensity criteria for moderate and vigorous physical activity, as stated in current physical activity recommendations for improving public health.
Introduction	The introduction has had a rewrite to ensure a more logical and concise argument. L.57 removed superfluous information L.67 changed Public Health to public health L.72-L.83 changed all spelling to handheld L.103 added references for the 3 studies L.103 changed assessed to compared L.107 clarified "s" and "SD" L.113 Changed & to and L.126-L.133 reworded to make a more logical paragraph.
Methods	L.138 changed 19 to Nineteen L.139-140 states how participants were recruited L.147 removed comma after self-report L.159-162 explained reason for taking resting blood pressure this was due to pre-screening and health and safety. L.180 changed to rate of perceived exertion (RPE) L.183-187 explained cut-points for RPE L.202 changed to mean ± SD

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	L. 206 deleted where
Results	Consistency has been established throughout the paper for *p* values L.216 p value actually p <0.05 not p >0.05 this has been changed and does not contradict the sentence. L.217 comma added after HR data and exercise intensity expressed as a % of HRmax L.220 game modes explained (AVG and SVG mean the modes) L.226-227- actual p values documented L.238-239 fitness of participants clarified. The authors feel it is not relevant to classify "somewhat hard" and "moderate" intensity exercise as this has already been mentioned in the methodology sections L.190-194. L.244 clarified the statement The authors reported p values as p <0.01 due to the statistical significance been so high at for example p = 0.000000001
Discussion	More critical analysis has been displayed in the discussion in relation to the papers secondary aim. L.268 Included reference to literature and included apostrophe in O'Donovan L.269 mean age was added as young adults, the authors felt this was more relevant to the reader than defining young adults. L.279 clarified the link to boxing games L277-282-Elaborated on the point L.285 noted that sample size was young boys L.291 changed to "The MET of running.." L.291 Highlights that the present study is being referred to.
Practical Implications	L.320 subscript max Reworded last practical implication.
Tables	Included overall mean ± SD to Table III, due to additionally adding a table for ACSM guidelines this is now Table IV

Reviewer 2

L. 121-122- Explaining that AVG has been compared to SVG gaming previously.

L.301-304 – explains that AVGs can be used as an alternative to PA and explains further works needs to be carried out.

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L. 304-311 highlights the debate for the use of the XBOX Kinect as an active game and refers to Forde and Hussey (2014) paper on " How Children Use Active Videogames and the Association Between Screen Time and Physical Activity).

L.321 Deleted comments about rehabilitation as the manuscript does not take this into account.

Last bullet point in the recommendations was deleted as the author(s) felt it was a repetition of point one.

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