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Original article (short paper)

Improving aerobic capacity through active videogames: A randomized controlled trial

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Abstract— The rate of peak workload improvement between different types of Active Video Games (AVG) in young sedentary adults was investigated. Aerobic capacity improvement after a 6-week intervention between AVG types was also compared. Twenty participants, after baseline assessments, were randomized into one of three parallel groups: structured AVG (*n* = 6), unstructured AVG (*n* = 7) and a control group (*n* = 7). Participants played their respective AVG 3 times a week for 6-weeks (30 minutes-session). The control group maintained normal activities. Both structured and unstructured AVG improved peak workload after four weeks but only the structured group maintained this improvement through week five and six. Aerobic capacity improved in the unstructured (Pre: 36.0 ± 5.2ml.kg.min-¹,Post: 39.7 ± 4.9ml.kg.min-¹, *p* = .038) and structured AVG (Pre: 39.0 ± 5.9ml.kg.min-¹,Post: 47.8 ± 4.3ml.kg.min-¹, *p* = .006) groups. Structured AVG provide greater health benefits to aerobic capacity and peak workload in young sedentary but otherwise healthy males relative to unstructured AVG.

Keywords: exercise, videogames, physical fitness

Resumo—"Melhora da capacidade aeróbica através de videogames ativos: Um estudo controlado randomizado." A velocidade de aparecimento de melhoria de potência de diferentes tipos de Video Games Ativos (VGA) em adultos jovens foi investigada. A melhora da capacidade aeróbia após uma intervenção de 6 semanas de diferentes VGAs também foi comparada. Vinte participantes após avaliações iniciais foram divididos aleatoriamente em três grupos paralelos: VGA estruturado (*n* = 6), o VGA não estruturados (*n* = 7) e um grupo controle (*n* = 7). Os participantes realizaram suas respectivas 3 vezes por semana de VGA durante 6 semanas (30 minutos por sessão). O grupo controle manteve suas atividades normais. Ambos estruturado e não estruturado melhoram a potência depois de quatro semanas, mas somente o grupo estruturado manteve esta melhoria nas semanas cinco e seis. A capacidade aeróbica foi melhorada tanto no VGA não-estruturado (Pre: 36,0 ± 5,2ml.kg.min-¹, Post: 39,7 ± 4,9 ml.kg.min-¹, *p* = 0,038) e estruturado (Pre: 39,0 ± 5,9ml.kg.min-¹,Post: 47,8 ± 4,3ml.kg.min-¹, *p* = 0,006). O VGA estruturado proporcionou maiores benefícios na saúde da capacidade aeróbica e a potência em homens jovens sedentários, em relação ao VGA não-estruturado.

Palavras-chave: exercício, video games, treinamento físico

Resumen—"Mejora en la capacidad aeróbica a través de juegos de vídeo activos: un estudio controlado seleccionado al azar." La tasa de mejoría mayor volumen de trabajo entre los diferentes tipos de Juegos de Video Activos (VJA) en jóvenes adultos sedentarios fue investigado. Mejoras de la capacidad aeróbica después de una intervención de 6 semanas entre los tipos de AVG también se comparó. Veinte participantes, después de evaluaciones de referencia, fueron aleatorizados en uno de tres grupos paralelos: VJA estructurado (*n* = 6), VJA no estructurada (*n* = 7) y un grupo control (*n* = 7). Los participantes jugaron sus respectivos VJA 3 veces por semana durante 6 semanas (30 minutos-sesión). El grupo control mantuvo sus actividades normales. Trabajo máximo fue mejorado pelo dos VJA después de cuatro semanas, pero sólo el structurado mantuvieron esta mejora en la semana cinco y seis. La capacidad aeróbica fue mejorado por tanto la no estructurada (Pre: 36,0 ± 5,2ml.kg.min-¹, Post: 39,7 ± 4,9 ml.kg.min-¹, *p* = 0,038) y estructurada (Pre: 39,0 ± 5,9ml.kg.min-¹, Post: 47,8 ± 4,3ml.kg.min-¹, *p* = 0,006). VJA. Estructurado VJA ofrecer mayores beneficios para la salud en la capacidad aeróbica y la carga de trabajo máximo en jóvenes varones sedentarios pero por lo demás saludables relativas a VJA no estructurada.

Palabras claves: ejercicio, juegos de vídeo, aptitud física

Introduction

A growing percentage of the worldwide population has adopted a sedentary life style (WHO, 2000). Unfortunately, this has resulted in decreased physical activity (PA) levels, which has been shown to increase the risk of a number of hypokinetic diseases such as hypertension, obesity and diabetes (WHO, 2000). This increase in sedentary behavior is occurring in parallel to the development of numerous technologies that result in individuals spending more of their day on "screen time" (Altenburg, Hofsteenge, Weijs, Delemarre-van de Waal, & Chinapaw, 2012). Screen time is defined as time spent on the triad of watching TV, using computers, and playing videogames which discourages regular PA (Christie & Trout, 2007). For example, traditional videogames require less body movement and lower physiological costs when compared to watching TV while standing in children and young adults (Lanningham-foster *et al.*, 2010).

According to American College of Sports Medicine (ACSM), young adults should perform 30 to 60 minutes of moderate PA (50 to 69% of maximum heart rate) at least 5 days a week to maintain cardiovascular health (Garber *et al.*, 2011) when appropriately evaluated and advised by a health professional. This document supersedes the 1998 American College of Sports Medicine (ACSM. Recent efforts to reduce screen time and promote PA has resulted in active videogames (AVGs) which have been shown to elevate levels of daily PA (Bailey & McInnis, 2011; Finco, 2010). There are two primary types of AVGs. Unstructured video games promote physical activity through gameplay but do not require formal movement patterns and do not have systematic progressions to more demanding levels of physical activity as game play progresses. These games are generally designed for recreation, motivation, and/or rehabilitation (Falcade, Baroncini, & Hanna, 2013; Perrier-melo, Brito-gomes, Fernandes, Oliveira, & Costa, 2013; Taylor *et al.*, 2012).

Structured video games are designed to improve physical fitness within a virtual reality environment by adhering to the principles of sport training. As a result, these games require formal completion of traditional exercises (e.g. squats, cycling) and systematically progress players by increasing the difficulty of the movements as game play progresses (Christie & Trout, 2007; Kraft, Russell, Bowman, SelsorIII, & Foster, 2011; Warburton *et al.*, 2007). Previous research has shown that a structured cycling AVG significantly improves the peak aerobic capacity workload in overweight and obese adolescents after 10 weeks of play (Adamo, Rutherford, & Goldfield, 2010). Similarly, young adults (18-25 years) saw a significant improvement in aerobic capacity after only 6 weeks of a structured AVG intervention (Warburton *et al.*, 2007).

While evidence supports the use of structured AVG to promote aerobic capacity, it is unclear if unstructured AVGs can improve aerobic capacity as effectively as structured AVG. Therefore the primary purpose of this investigation was to determine how quickly AVG, structured and unstructured, improve peak workload (w) in young sedentary adults. The secondary purpose of this investigation was to determine which type of AVG, structured or unstructured, result in greater aerobic capacity (ml.kg.min^{-1}) improvements after a 6-week intervention.

We hypothesized that both structured and unstructured AVG will improve aerobic capacity (peak workload - w) in less than 6-weeks but that the structured AVG would result in greater aerobic capacity (ml.kg.min^{-1}) improvements. This hypothesis was based on the inclusion of fitness principles within the structured AVG.

Method

Design and participants

This Brazilian non-blinded parallel group randomized controlled trial (registration number: U1111-1159 7242) was conducted in the Laboratory Evaluation in Human Performance CENESP/ESEF/UPE, Recife-PE, in 2014. The participants were recruited through university advertisements and word of mouth. The sample included 24 volunteer normotensive university students between 18 and 25 years of age (age: 19.8 ± 2.0 years, height: 1.78 ± 0.07 m, weight: 73.0 ± 9.5 kg). A power analysis (GPower Software, version 3.1.9) indicated that a sample of 18 participants (6 each group) was needed to identify significant pre to post differences with >80% power and a 5% level of significance. All participants were healthy eutrophic males who were physically inactive (3 months with no structured physical activities) and had no previous experience playing AVG. All participants read and signed the informed consent form approved by the University of Pernambuco (UPE) Research Ethics Committee (Number approval: 858 209; Approval date: 03/11/2014) prior to participation. Additionally, all participants were screened using the Physical Activity Readiness Questionnaire (PAR-Q) prior to initiating the investigation.

Procedures

Once eligible, participants underwent baseline testing to determine body weight, height, resting heart rate, blood pressure, aerobic capacity, and peak workload. Body weight and height (Stewart, Marfell-Jones, Olds, & Ridder, 2012) were used to calculate the Body Mass Index (BMI) by kilogram per square meter. All hemodynamic measurements were captured after resting for five minutes in a seated position. Heart rate (HR) was assessed by using a Polar FT1 (Polar, Finland) heart rate monitor. Next the systolic blood pressure (SBP) and diastolic (DBP) were measured using an automated blood pressure machine (OMRON HEM- 7113) according to Guidelines of Brazilian Hypertension (Nobre, 2010). Peak workload was obtained during a maximal Astrand-Ryhming cycle test performed on a Cateye EC-1600 Ergociser (Ergociser, Japan) following the protocol used by the ACSM (Astrand & Ryhming, 1954). In brief, this test is completed by an initial 2 minute warm up at 25 watts. Participants then completed a 2-minute stage at 100 watts before adding 50 watts every 2 minutes until fatigue. During the baseline and post intervention maximal cycle test, all participants wore a face mask and adult head cap (Metalyser, Germany) connected to a metabolic gas analyzer (CPX/D, Cortex, Germany) to determine aerobic capacity. For the baseline and all subsequent assessments, participants were instructed to wear minimal clothing, to avoid moderate or vigorous exercise for 24 hours prior to testing, to eat at least three hours before the assessment, and to refrain from alcohol and smoking the day prior. No changes to the trial design were made after the initiation of the trial.

Randomization and experimental trial intervention

After completing the baseline assessment, participants were randomized to one of three groups: a) Unstructured AVG (Kinect Sports: boxing), b) Structured (Nike Kinect training) and c) Control (normal daily activities). Kinect Sports: Boxing was chosen as the unstructured AVG because boxing related games have consistently demonstrated the ability to significantly increase heart rate as well as energy expenditure and to do so more than many other unstructured AVG (Falcade, Baroncini, & Hanna, 2013; Perrier-Melo, Brito-Gomes, Fernandes, Oliveira, & Costa, 2013; Taylor *et al.*, 2012). However, it is important to note that the Kinect Sports: Boxing AVG differs from formal boxing training. Specifically, it does not require specific movements to be made (i.e., proper boxing technique) and does not increase activity intensity (e.g., number of punches, rate of punches thrown, etc.) as game play progresses. As a result, the game promotes physical activity through a fun and free game play environment that is unstructured. Nike Kinect Training was chosen because the gameplay mimics exercising with a fitness professional. Specifically, the games requires an initial fitness assessment and progresses players to more demanding exercises systematically in correlation with progression in the game. Thus, the game met the operational definition of a Structured AVG. Table 1 provides the characteristics that were used as part of the current operational definition of structured and unstructured AVGs.

Table 1. Active videogames characteristics.

Division	Characteristics	Games
Structured	Uses basic exercises such as squats, push-ups, cycling. Incorporates planned movement patterns. Movement pattern feedback may or may not be provided based on the operating system. Systematic order of exercise progression and/or intensity (e.g. sets, reps, rate, duration).	Gym Games Your Shape Fitness Game bike Nike Kinect Training
Unstructured	Activities that do not mimic formal exercises but rather sporting movements and general body movements. Players are free to move as they wish during game play and there is no formal progression to higher levels of physical activity difficulty as game play progresses.	Boxing Volleybal Table tennis Dance Dance revolution

Baseline aerobic capacity scores were rank ordered from highest to lowest and then allocated in the following order: 1) Unstructured; 2) Structured; 3) Control; 4) Control; 5) Structured; 6) Unstructured. This cycle was restarted as needed until all participants were assigned. Each treatment group then performed an AVG familiarization session. The unstructured group (boxing), performed 20 minutes of gaming and was allowed to see the tutorial videos of the game. The structured group (Nike training) performed a brief fitness assessment (~20 minutes) that the AVG provides to prescribe the exercises that were to be performed during gameplay and they were allowed to see the tutorial videos of the game.

All training sessions were completed with an Xbox 360º Kinect console. All AVG were displayed, via a multimedia projector (Ppower Lite S10+, EPSON) mounted to the laboratory ceiling, on a wall with an image size of approximately 1.3m high by 1.6m wide. Sound was broadcast via a single amplified speaker (COM 126 Professional, ONEAL, Brazil) connected to the Xbox 360º console. The laboratory was keep at 24 ± 2° C, with 40-60% relative humidity. Two days after baseline testing and game orientation, participants initiated the 6-week intervention. Each participant completed 3 sessions per week of the intervention for a total of 18 sessions (30 minutes each). The unstructured AVG is composed of 3-minute rounds of simulated punches against the computer and the participant can move from side to side and complete mini-squats as part of game play. The structured AVG is composed of different functional exercises of the limbs and core that emphasize body weight resistance. Exercises included in the structured AVG also require side to side movement as well as jumping and stationary running. Participants in the AVG groups were required to complete at least 90% of the training sessions or they would be dropped from the investigation. Each week and following the final training session participants completed another assessment of peak workload using the methodology described for the baseline assessment. Aerobic capacity was also assessed following the final 6-week training session but not on a weekly basis during the intervention.

Statistical analyses

All data initially underwent tests of normality (Shapiro-Wilk). After determining normal distribution of the data, baseline values (HR, BP, peak workload, aerobic capacity) were compared among the control, structured AVG, and unstructured AVG groups using separate one-way ANOVAs. Change in peak workload during the intervention was assessed using a repeated measure ANOVA. Tukey's *post hoc* test was used to identify the location of significant differences if appropriate. Finally, paired t-tests determined pre to posttest differences in aerobic capacity for each group. An a priori alpha level of .05 was used for all statistical tests.

Results

In total, four participants were excluded. Three for failing to complete at least 90% of the training sessions and one acquired an osteo-mio-articular injury, independent of the study protocol.The demographic and baseline assessments of the remaining 20 participants can be seen in Table 2. These participants were classified as having a normal aerobic capacity by both the ACSM and the American Heart Association (Garber *et al.*, 2011).

The change in peak workload of the structured and unstructured AVG groups and control group throughout the intervention period are presented at the Figure 1. Over time, the control group did not differ from the baseline assessment (p = .700). The unstructured AVG intervention resulted in a significant improvement in peak workload at week four, relative to baseline (p = .002), but this improvement was no longer significantly different from the baseline assessment (p > .05) at weeks five and six. The structured AVG also resulted in a significant improvement in peak workload at week 4 (p = .002) but this improvement was maintained at the fifth and sixth week (p = .005).

Table 2. Sample characterization recruited for the study (n = 20).

Variable	Unstructured (n = 7)	Structured (n = 6)	Control (n = 7)	p
Age (years)	18.8 ± 0.9	19.0 ± 1.0	21 ± 3	.454
Weight (kg)	72.3 ± 10.2	71.7 ± 13.7	69.2 ± 8.1	.616
Height (m)	1.70 ± 0.05	1.70 ± 0.06	1.77 ± 0.07	.746
BMI (kg/m²)	22.6 ± 2.0	23.6 ± 3.3	22.2 ± 4.3	.545
RHR (bpm)	79.0 ± 12.7	69.3 ± 2.3	78.0 ± 8.5	.292
RSBP (mmHg)	125.4 ± 10.8	124.8 ± 12.0	117.1 ± 11.3	.333
RDBP (mmHg)	68.5 ± 4.3	69.5 ± 7.7	69.6 ± 8.9	.960
AE (ml/kg/min-1)	36.0 ± 5.2	39.0 ± 5.9	37.9 ± 3.3	.572
Peak workload (w)	187.5 ± 57.7	216.7 ± 35.3	183.3 ± 28.9	.661

BMI – Body Mass Index; BPM – Beats per minute; RHR - Resting Heart Rate; RBP - Resting Systolic Blood Pressure; RDBP – Diastolic Blood Pressure; AE - Aerobic capacity.

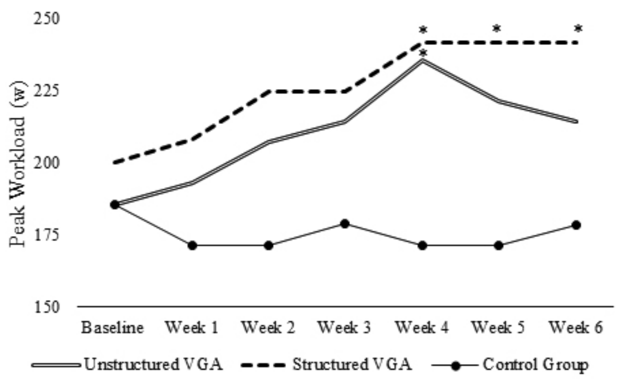

Figure 1. Peak workload of AVG and control group during the measuments. *Significant difference relative to baseline measurement (p < .05).

Aerobic capacity was also significantly improved, relative to baseline, at the end of the six-week intervention for the AVG groups. More specifically, unstructured AVG improved aerobic capacity from 36.0 ± 5.2ml.kg.min-^{1} to 39.7 ± 4.9ml.kg.min-^{1} (p = .021), while structured AVG improved aerobic capacity from 39.0 ± 5.9ml.kg.min-^{1} to 47.8 ± 4.3ml.kg.min-^{1} (p = .007). There was no change in the aerobic capacity of the control group (Baseline: 36.9 ± 4.5 ml.kg.min-^{1}, Post: 38.9 ± 3.7 ml.kg.min-^{1}; p = .214).

Discussion

The purpose of this investigation was to determine how quickly structured and unstructured AVG could improve peak workload in young adults and which type of AVG would result in greater aerobic capacity improvements. The results of this investigation support our a priori hypothesis that both structured and unstructured AVG would improve peak workload in less than six weeks as both groups resulted in significant improvements after 4-weeks. However, the decline of peak workload in the unstructured AVG group during the fifth and sixth week of the intervention suggests that only structured AVG can improve and maintain an increased peak workload in young healthy but sedentary adults. Our results also support our hypothesis that structured AVG would result in greater aerobic capacity improvements relative to unstructured AVG after six weeks of training. In fact, the participants of the structured AVG improved their aerobic classification from regular (34 – 42 ml/kg/min-1) to good (43 – 52 ml/kg/min-1).

Previous research has shown that peak workload can be improved in overweight and obese individuals after 10 weeks of a structured cycling AVG (Adamo *et al.*, 2010). Similarly, the peak workload of healthy young adults (18-25 years) improved after only 6 weeks of a structured AVG intervention (Warburton *et al.*, 2007). These results are consistent with those observed in the current investigation and cumulatively suggest that structured AVG played 3 times a week as recommended by the ASCM can provide health benefits in as early as four weeks across different populations (Garber *et al.*, 2011). However, it is difficult to determine the effectiveness of unstructured AVG as no other investigation has quantified their effect on peak workload after a scheduled intervention program. Several investigations have demonstrated that unstructured videogames result in an elevated heart rate (Falcade *et al.*, 2013; Naugle, Naugle, & Wikstrom, 2014; Perrier-melo *et al.*, 2013; Taylor *et al.*, 2012) but no other evidence is available to compare the effects of an unstructured AVG as a formal intervention. Based on the current results alone, it would appear that an unstructured AVG may be an effective early intervention but participants may need to transition into a more structured exercise regimen to maintain fitness gains. However, this is speculative and further research using a breadth of unstructured AVGs should be conducted to test this hypothesis.

Greater improvements in aerobic capacity were also observed in the structured AVG group (22.67%; Effect size = 1.42, 95%CI: 0.15 to 2.68) relative to the unstructured AVG group (10%; Effect size = 0.53, 95%CI: -0.53 to 1.60) and the control group (Effect size = 0.45, 95%CI: -0.61 to 1.51). The large effect size and confidence interval that do not cross zero clearly indicate that six-weeks of a structured AVG intervention is an effective modality to improve cardiovascular fitness in young sedentary but otherwise healthy adults. Further, the observed improvements are consistent with those in the literature using more traditional exercise programs. For example, VO2max improvements of 16.7%, 22.5%, and 10% were observed with sprint interval training, high-intensity interval aerobic training, and continuous aerobic training respectively in healthy but sedentary adults (26.5 years) after 40 training sessions over an eight week supervised intervention (Matsuo *et al.*, 2014). Matsuo *et al.* also noted that young healthy but sedentary adults (29.2 years) had a 22.4% and 14.7% improvement in VO2max after 24 training sessions over eight weeks (3 days a week) of supervised high-intensity interval training and moderate-intensity continuous aerobic training respectively (Matsuo *et al.*, 2014). Similarly, Sloan *et al.* illustrated an ~10% improvement in aerobic capacity in young healthy but sedentary adults (30.4 years) after completing 36-48 training sessions during a 12 week progressive aerobic exercise intervention (Sloan *et al.*, 2009).

However, it should be noted that the current results were observed with a supervised training intervention and may not be as profound if the training intervention was unsupervised. Evidence has shown that engaging in exercise behavior is influenced by a number of affective variables including positive affective responses (Williams, 2014; Schneider, Dunn, & Cooper, 2009). Previous research has shown that unstructured AVG are more enjoyable than traditional exercise modalities (e.g., treadmill walking) during a single exercise bout (Naugle, Naugle, & Wikstrom, 2014) but no research has quantified the affective response to structured AVG during a single exercise bout or over a prolonged training intervention (Graves *et al.*, 2010). It is unlikely that "screen time" will dramatically reduce in the near future but the use of AVG may provide opportunities to reduce sedentary habits and promote cardiovascular fitness as outlined by the ACSM (Haskell *et al.*, 2007). While structured AVG increased aerobic capacity by 22.67%, relative to the 10% increase in unstructured AVG, these effects will only be achieved if individuals chose to participate in this activity. Future research is needed to quantify the affective response to both structured and unstructured AVG during a training intervention which may be different than the response initially felt during a single bout of exercise. Similarly, research on which type of AVG or a combination of structured and unstructured AVG results in the greatest adherence rate is also needed.

This investigation is not without limitations. First, we used a sample of only young adult males. Research has shown that men and women have different exercise motivations, attitudes towards video gaming (Graf, Pratt, Hester, & Short, 2009) and also cognitive functions (Teixeira-Arroyo *et al.*, 2014). These differences may result in different exercise intensities during game play and subsequently different changes in peak workload and aerobic capacity. In addition, the current investigation only used a single structured and unstructured AVG. Previous research has shown that not all games produce the same cardiovascular response (Miyachi, Yamamoto, Ohkawara, & Tanaka, 2010) or have the same affective response (Naugle *et al.*, 2014). Future research is needed to test the effectiveness of a broad range of structured and unstructured AVG as well different combinations of games to optimize the health benefits observed from AVG.

Conclusion

This data suggest the structured AVG can provide health benefits as measured by aerobic capacity and peak workload in as little as four weeks. Further, the data indicate that structured AVG result in significantly greater improvements in aerobic capacity after six weeks when compared to unstructured AVG in young sedentary but otherwise healthy adults. Consequently, results indicate that incorporation of structured active videogames into routine training may be a viable option for enhancing physical activity. This would suggest that structured AVG within a virtual environment may be a practical solution to improving physical fitness for sedentary young adults because of their integration in screen time devices but further research is needed to confirm this hypothesis.

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Additional information
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