



## PHYSICAL EFFORT, ENERGY EXPENDITURE, AND MOTIVATION IN STRUCTURED AND UNSTRUCTURED ACTIVE VIDEO GAMES: A RANDOMIZED CONTROLLED TRIAL

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### ABSTRACT

**Purpose.** The goals of the study were: a) to compare the way that two types of active video games (AVG) influenced physical effort and motivation in young adults; b) to compare direct and indirect instruments and use an indirect instrument (heart rate analysis) as a practical tool to verify physical effort in AVGs. **Methods.** Initially, 16 healthy but physically inactive young adult males with no AVGs experience took part in the randomized control trial. After the baseline assessments of blood pressure (BP), heart rate (HR), and aerobic capacity (AE), the participants were randomized into two groups: structured AVG ( $n = 6$ ) and unstructured AVG ( $n = 7$ ) (3 dropouts). They played 3 sessions a week, during 6 weeks. Direct and indirect metabolic measurements were made. To compare direct and indirect AE, Student *t*-test was used for related samples. Changes (group  $\times$  time) in HR, perceived exertion (PE), calculated energy expenditure (EE), calculated metabolic equivalent (MET), and motivation (points) were assessed with the two-way analysis of variance. **Results.** There were no differences between direct and indirect AE ( $36.0 \pm 5.2$  vs  $33.9 \pm 6.0$  ml/kg/min: unstructured;  $39.0 \pm 5.9$  vs  $37.7 \pm 5.9$  ml/kg/min;  $p > 0.05$ ). No differences were observed in maximal HR, PE, or motivation ( $p > 0.05$ ). Statistically significant differences referred to average HR, MET, and EE over the sessions ( $p < 0.05$ ). HR and EE values were higher in structured than in unstructured AVGs. **Conclusions.** HR and EE responses of structured AVGs turned out higher than those of unstructured AVGs, and the measurements proved efficient to analyse physical effort in AVGs in a long-term perspective.

**Key words:** exercise, play and playthings, aerobic capacity, heart rate, physical activity

### Introduction

Decreased physical activity (PA) levels increase the risk of a number of diseases, such as hypertension, diabetes, and overweight and obesity [1]. However, several studies with different modalities of PA have been performed in order to promote higher PA levels; an example is active video games (AVGs), which have been shown to achieve this goal [2, 3] and to be a good tool to motivate adults to exercise [4].

There are two primary types of AVGs: unstructured, designed for recreation, motivation, and/or rehabilitation [5–7]; and structured, aiming at physical fitness improvement in a virtual reality environment by adhering to the principles of sports training [8, 9]. In addition, motivation is a factor that may acutely differentiate the AVG types. Unstructured AVGs resembling sports games are considered more motivating than structured physical education activities [10].

This differentiation remains in accordance with the recommendations of physical fitness centres: structured games provide approximation criteria established to increase the effectiveness of exercise programs based on training periodization [11]. To achieve these goals

it becomes essential to consider other factors, such as frequency, duration, volume, and intensity of the activities [12]. Thus, structured AVGs apply to these characteristics, while unstructured AVGs are games based on recreational and sports physical activities.

Previous research has shown that a structured AVG (3 times a week of cycling) significantly improves the cardiovascular fitness in overweight and obese adolescents after 10 weeks of play [13]. Similarly, young adults (18–25 years; 3 times a week) presented a significant cardiovascular fitness improvement and reductions in maximal heart rate (HR) after only 6 weeks of structured AVG intervention [9]. Unstructured AVG intervention (DDR, Dance Dance Revolution AVG; 10 weeks) was also verified to change cardiovascular fitness. Nevertheless, in a 10-week study with an unstructured AVG (DDR AVG intervention), a reduction was observed of light PA during the day and elevation of vigorous PA in the participants' lives. It can be thus concluded that AVGs promote the elevation of basal metabolism [14].

Whereas there is evidence supporting the use of structured and unstructured AVGs to promote changes in cardiovascular fitness, only within 6 weeks, resulting in hemodynamic modifications, and the impact of unstructured AVGs on changes in physical effort is unquestionable, none of the performed studies analysed the two AVG types comparatively. Secondly, according to

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several studies referring to physical effort indicators (metabolic equivalents [MET], energy expenditure [EE], and others), to our knowledge, the measurements were performed in short-term settings because of gold standard high cost in a long-term analysis. Moreover, in practical terms, people practicing AVGs would rarely use the gold standard instruments to control their sessions. In these cases, the HR (or power work capacity, if the HR of 170 bpm during physical activity is reached, PWC170) and perceived exertion (PE) are recommended as means to evaluate the intensity of physical effort.

Thus, two critical problems seem to remain unsolved in the literature:

1) how different structured and unstructured AVGs change the physical effort (intensity of the sessions) and motivation to play them,

2) a comparison of the direct and indirect instruments and usage of an indirect instrument (HR analysis) as a practical tool to verify physical effort in AVGs in a long-term analysis.

Therefore, the primary purpose of this investigation was to compare the two different types of AVGs in the context of their impact on the physical effort and motivation in young adults. The secondary purpose of the study was to compare the direct and indirect instruments and to use an indirect instrument (HR analysis) as a practical tool to verify physical effort in AVGs.

## Material and methods

### Design and participants

This Brazilian non-blinded parallel group randomized controlled trial (registration number: U1111-1159 7242) was conducted in the Human Performance Laboratory CENESP/ESEF/UPE, Recife-PE, in 2014. The participants were recruited voluntarily through university advertisements and word of mouth. The sample included 16 volunteer normotensive university students aged between 18 and 25 years (age:  $19.4 \pm 1.6$  years; height:  $1.78 \pm 0.07$  m; weight:  $74.1 \pm 10.3$  kg). The power analysis (GPower software, version 3.1.9) indicated that a sample of 6 participants per 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 activity) and had no previous experience with playing AVGs. All of them read and signed the informed consent form, approved by the University of Pernambuco Research Ethics Committee (#858 209) prior to participation. Additionally, the participants were screened with the Physical Activity Readiness Questionnaire (PAR-Q) prior to initiating the investigation.

### Baseline assessments

Once eligible, the participants underwent baseline testing to determine their body weight, height, resting HR, blood pressure, aerobic capacity (AE; maximal  $\text{VO}_2$ ), and peak workload.

### Anthropometric assessments

The body weight and height were used to calculate the body mass index (BMI), expressed in kilograms per square metres [15].

### Hemodynamic and inotropic assessments

All the hemodynamic measurements were performed after resting for 5 minutes in a seated position. HR was evaluated with a Polar FT1 (Polar, Finland) HR monitor. Next, the systolic (SBP) and diastolic blood pressure (DBP) were measured with an automated blood pressure machine (OMRON HEM-7113) according to the Brazilian Guidelines on Hypertension [16].

### Maximal $\text{VO}_2$ assessment

Baseline and weekly aerobic measurements (direct and indirect) were made. During the baseline maximal cycle test, all participants wore a face mask and an adult head cap (Metalyzer, Germany) connected to a metabolic gas analyser (CPX/D, Cortex, Germany) to determine AE. In the following weeks, indirect analyses (peak workload) were carried out during a maximal Astrand-Ryhming cycle test performed on a Cateye EC-1600 Ergociser (Ergociser, Japan) according to the protocol applied by the American College of Sports Medicine (ACSM) [17] (the same test was used in baseline measurements). In brief, the test is completed by an initial 2-minute warm-up at 25 watts. The participants then completed a 2-minute stage at 100 watts before adding 50 watts every 2 minutes until volitional fatigue. For the baseline and all subsequent assessments, the participants were instructed to wear minimal clothing, to avoid moderate and vigorous exercise for 24 hours prior to testing, to eat at least three hours before the assessments, and to refrain from alcohol and smoking the day before. No changes to the trial design were introduced after its initiation.

### Training sessions and randomization

After completing the baseline assessment, the participants were randomized to two groups: a) structured AVG (Kinect Sports: Boxing), and b) unstructured AVG (Nike Kinect Training). AE scores were rank ordered from highest to lowest and then allocated in the groups one by one. The cycle was restarted as needed until all participants were assigned.

Each study group then performed their AVG familiarization session. The structured group (Nike Kinect Training) underwent a brief evaluation (~20 minutes) indicating that the AVG provided the exercises that were to be performed during gameplay, and were allowed to watch the tutorial videos of the game. The unstructured group (Boxing) played the game for 20 minutes and were allowed to watch the tutorial videos of the game.

All the training sessions were completed with an Xbox 360° Kinect console (Microsoft). All AVGs were displayed via a multimedia projector (PowerLite S10+, EPSON) mounted to the laboratory ceiling, on a wall with an image size of 1.3 m height and 1.6 m width. The sound was broadcast through a single amplified speaker (COM 126 Professional, ONEAL, Brazil) connected to the Xbox 360° console. The laboratory was kept at the temperature of 24 ± 2°C, with 40–60% relative humidity.

Two days after the baseline testing and game orientation, the participants initiated the 6-week intervention – only in the randomized group (structured or unstructured AVG). Each participant completed 3 sessions per week (total: 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 minisquats as part of the game play. The structured AVG consists of different functional exercises of the limbs

and core that emphasize body weight resistance. The exercises included in the structured AVG also require side-to-side movement, as well as jumping and stationary running. The participants in both AVG groups were required to complete at least 85% of the training sessions or they would be dropped from the investigation (Figure 1).

Energy expenditure and motivation assessment

In each session, also other assessments were completed: maximal HR, average HR, PE, EE, MET, and motivation. Maximal and average HR were evaluated with a Polar FT1 (Polar, Finland) HR monitor, analysing the values after the end of the session. PE was assessed using the Borg Scale (6–20 points), once, after the end of the session according to Gunnar Borg orientations [18], recorded with the verbal response of the participant after visualizing the 6–20 points of the Borg Scale. EE and MET were calculated with the sequence of the following mathematical formulas (steps 1–4):

$$VO_{2max} \text{ (ml/kg/min)} = \frac{\text{peak workload (watts)} \times 12 \text{ ml/min} + 300 \text{ ml/min}}{\text{body weight (kg)}}$$

Step 1. Calculate the maximal VO<sub>2</sub> [19] of the week  
 Note: Each week recalculated to analyse the 3 sessions of each week. The maximal VO<sub>2</sub> obtained by this formula is the calculated maximal VO<sub>2</sub> used to (re)calculate the MET and EE of the sessions over the weeks

$$\text{intensity of } VO_{2max} \text{ (\%IVO}_{2max}) = \frac{\text{average HR} - \text{resting HR}}{\text{maximal HR} - \text{resting HR}}$$

Step 2. Calculate the intensity of the maximal VO<sub>2</sub> [20] of the sessions using the heart rate during the sessions (3 sessions)

Average HR – medium heart rate during the game, resting HR – resting heart rate in a sitting position, maximal HR – the highest heart rate during the game

$$\text{session's METs (ml/kg/min)} = \frac{VO_{2max} \text{ (ml/kg/min)} \cdot IVO_{2max}}{3.5 \text{ (ml/kg/min)}}$$

Step 3. Calculate the metabolic equivalent (MET) of the session [21]

$$EE \text{ (kcal/min)} = \frac{(\text{sessions's MET} \times \text{body weight [kg]} \times 3.5)}{200} \times \text{physical activity duration}$$

Step 4. Calculate the energy expenditure (EE) [19]

The motivation was assessed at the end of each session with the use of the Visual Analog Scale [22] adapted for AVGs [23], consisting of a pen scratching in a non-numeric scale of 10 cm, later measured with a ruler.

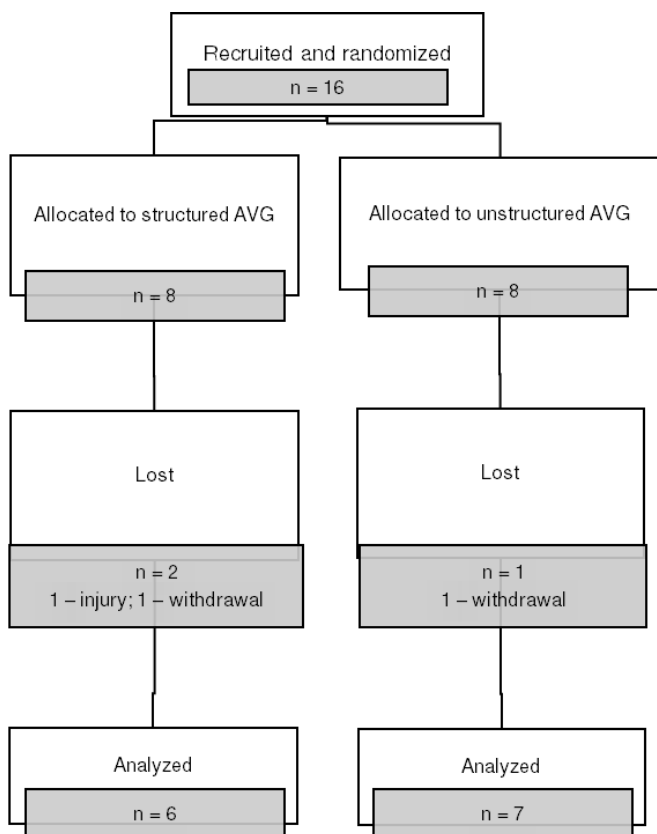


Figure 1. Eligibility criteria for participants AVG – active video game

Table 1. The demographic and baseline characteristics of the participants  
( $n = 13$ ; no difference between the groups;  $p > 0.05$ )

Variable	Unstructured AVG ( $n = 7$ )	Structured AVG ( $n = 6$ )	$p$
Age (years)	18.8 ± 0.9	19.0 ± 1.0	0.158
Body weight (kg)	72.3 ± 10.2	71.7 ± 13.7	0.266
Height (m)	1.70 ± 0.05	1.70 ± 0.06	0.292
BMI (kg/m <sup>2</sup> )	22.6 ± 2.0	23.6 ± 3.3	0.582
HR (bpm)	79.0 ± 12.7	69.3 ± 2.3	0.206
SBP (mm Hg)	125.4 ± 10.8	124.8 ± 12.0	0.675
DBP (mm Hg)	68.5 ± 4.3	69.5 ± 7.7	0.941
Direct AE (ml/kg/min)	36.0 ± 5.2*	39.0 ± 5.9**	0.457
Estimated AE (ml/kg/min)	33.9 ± 6.0*	37.7 ± 5.9**	0.075
Peak workload (watts)	187.5 ± 57.7	216.7 ± 35.3	0.465

AVG – active video game, BMI – body mass index, HR – heart rate, bpm – beats per minute, BPP – systolic blood pressure, DBP – diastolic blood pressure, AE – aerobic capacity

\*  $p = 0.068$ ; \*\*  $p = 0.718$ ;  $p > 0.05$  reflects no difference between the direct and calculated AE

### Data analysis

Initially, all the data underwent tests for normality (Shapiro-Wilk). After determining the normal distribution of the data, baseline values (HR, BP, peak workload, as well as direct and indirect AE analyses) were compared between the structured and unstructured AVG groups; separate Student *t*-tests for independent samples were applied. To compare the differences between the values for the direct and indirect AE, Student *t*-tests for related samples were employed. Changes (group × time) in HR, PE (Borg Scale points), EE, MET, and motivation were assessed with the two-way analysis of variance (ANOVA). Tukey's *post hoc* test was used to identify the location of significant differences if appropriate. An *a priori* alpha level of 0.05 was used for all statistical tests.

### Results

In total, 3 participants were excluded: 1 acquired an osteoarticular injury independent of the study protocol that precluded practicing physical activities in the study, and 2 failed to complete at least 85% of the training sessions. The demographic data and baseline assessments of the remaining 13 participants are presented in Table 1. The participants were classified as having normal AE according to both the ACSM and the American Heart Association [12, 24].

The physical effort as expressed by HR and PE during the sessions over 6 weeks are presented in Figure 2. The maximal HR and average HR during the AVG intervention over 6 weeks are reflected in panels A and B, respectively. The maximal HR showed no statistically significant difference among the sessions ( $p = 0.873$ ), and the average HR differed significantly at the 4<sup>th</sup> session in comparison to the 14<sup>th</sup> and 18<sup>th</sup> sessions ( $p =$

0.000). The PE (panel C) illustrates no statistically significant difference between the groups ( $p = 0.796$ ).

The changes in MET and EE in the structured and unstructured AVG groups throughout the intervention period are presented in Figure 3. MET (panel A) and EE (panel B) show differences between the familiarization session and the 13<sup>th</sup> session, with  $p = 0.013$  and  $p = 0.039$ , respectively.

Motivation to play, shown in Figure 4, presented no significant differences between the AVG groups ( $p = 0.796$ ).

In extra analyses, the effect size of the EE, MET, PE, and motivation was obtained by the variance of each variable with the use of GPower software, version 3.0. In structured AVG, the effect sizes were 0.82, 0.84, 1.02, and 0.98 respectively. In unstructured AVG, the effect sizes equalled 1.11, 1.13, 1.24, and 0.94, respectively. Thus, all variables in both AVG groups were considered to have a strong effect size.

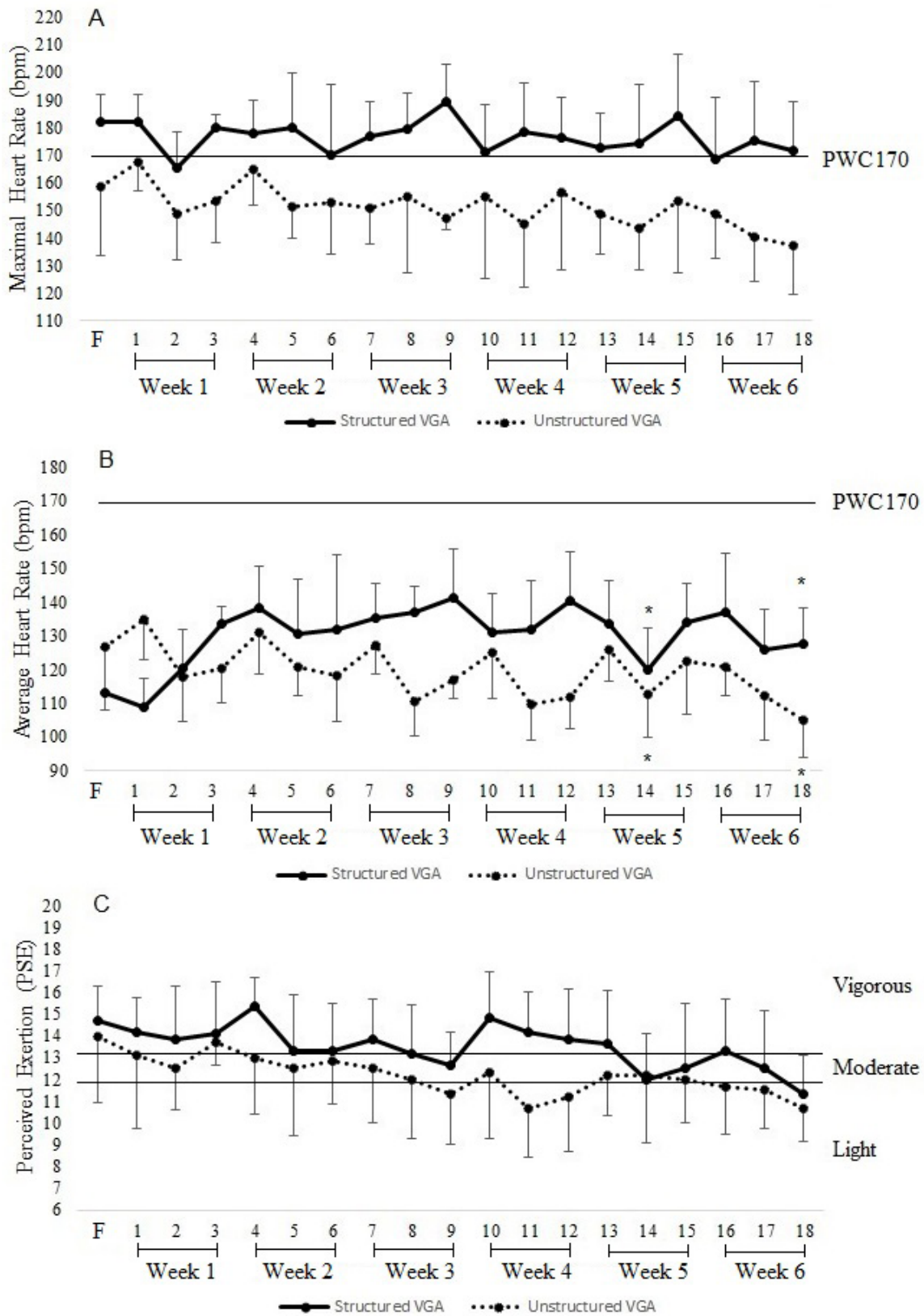
### Discussion

To our knowledge, this is the first study evaluating the cardiovascular responses and direct and indirect EE measurements in the context of different types of AVGs in a longer perspective. Previous investigations referred to short-term interventions [25] or an acute response [26, 27]. Only the study by Warburton et al. (2007) concerned the same period as the present investigation [9]. This aspect should be noted in view of the recommendations to use AVGs in domestic and recreational environments for longer periods of virtual exercise intervention.

Regarding the intensities achieved in games, the main findings of the study were the following:

a) structured and unstructured AVGs present similarities in the responses of HR and indirect EE during 6 weeks of intervention,

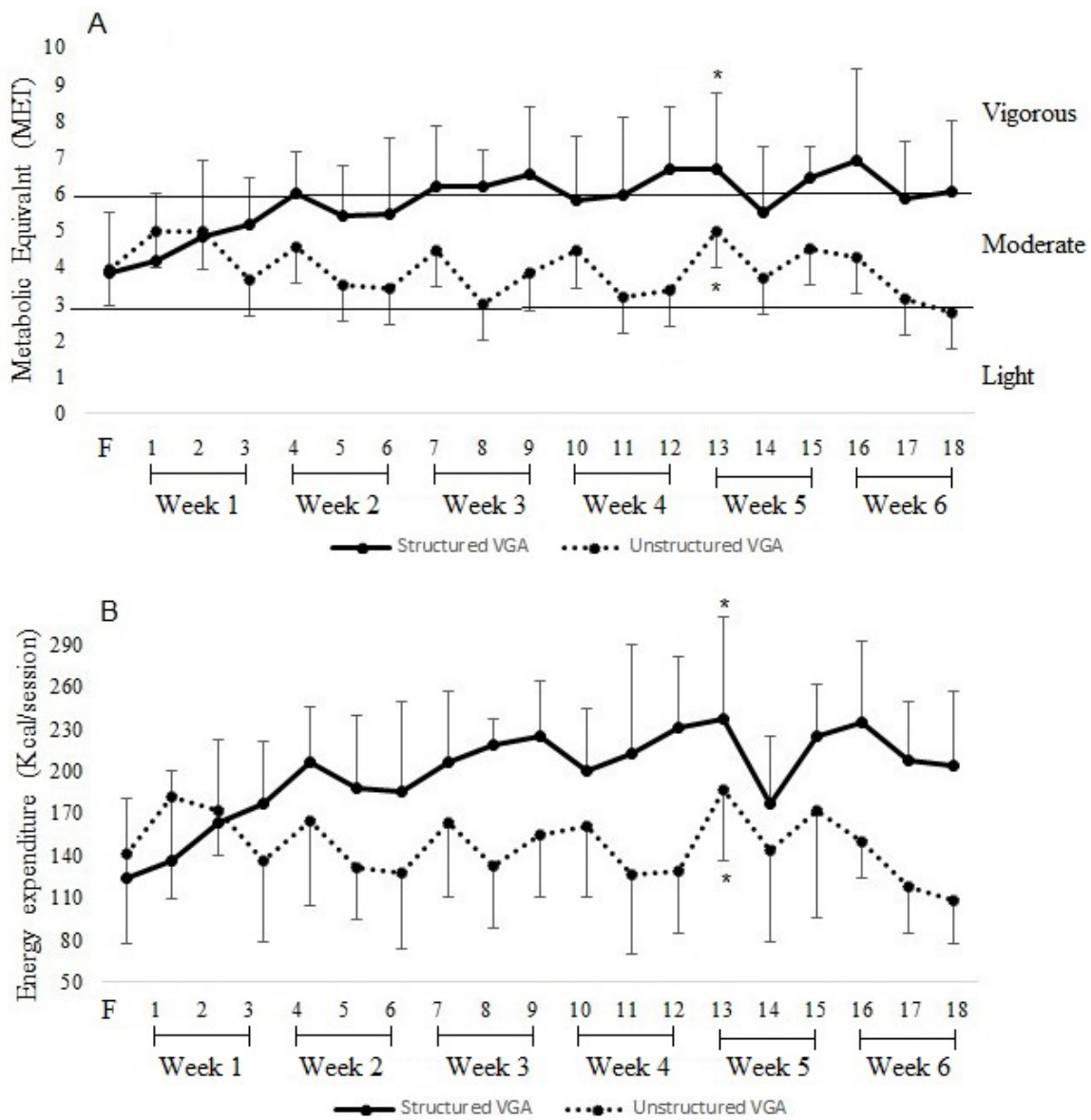




\* significant difference between session 4 and sessions 14 and 18 ( $p < 0.05$ )

Figure 2. Maximal (A) and average (B) heart rate, and perceived exertion (C) during the AVG intervention over 6 weeks  
 Bpm – beats per minute, PWC170 – power work capacity reaching 170 bpm, F – familiarization,  
 AVG – active video game, 1–18 – session numbers

Note 1: Panel C presents the physical effort level (light, moderate, and vigorous) expressed by perceived exertion in the AVG sessions according to ACSM.



\* significant difference between the familiarization session and session 13 ( $p < 0.05$ )

Figure 3. Metabolic equivalent (A) and energy expenditure (B) during the AVG intervention over 6 weeks  
F – familiarization, AVG – active video game, 1–18 – session numbers

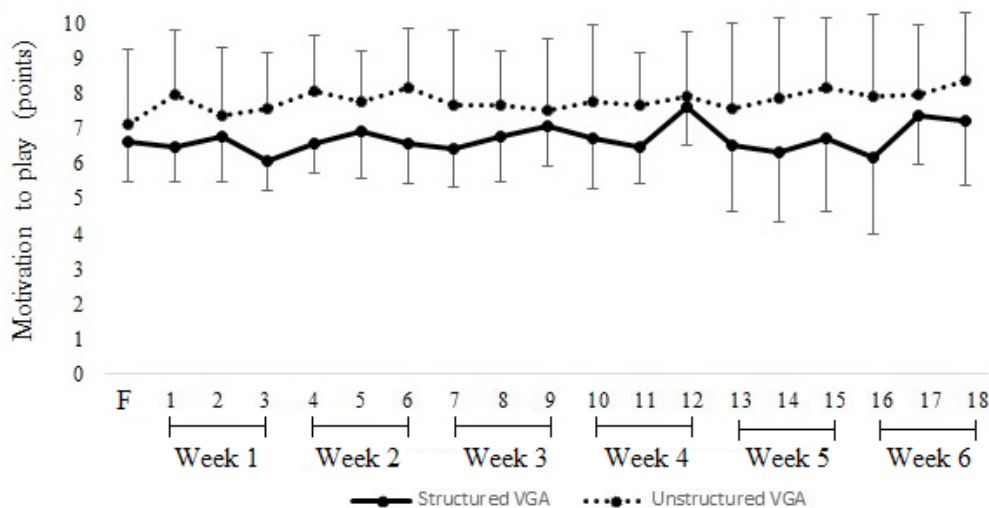


Figure 4. Motivation to play in each AVG group over 6 weeks  
F – familiarization, AVG – active video game, 1–18 – session numbers

b) structured AVGs remained in higher levels of the HR response (maximum and average) values as compared with unstructured AVGs (maximal HR: 177 bpm *vs* 151 bpm; average HR: 130 bpm *vs* 119 bpm, respectively).

Based on these results, the use of AVGs in order to improve fitness or increase the PA levels could be recommended for healthy young people, in agreement with previous research that had already recommended such activities with moderate or vigorous intensities [28, 29]. However, although significant differences were not observed, structured AVGs, which promote increments by various exercises and use progression of intensity loads, are found to be more effective in keeping intensity levels near PWC170 during all intervention sessions, which means a rise in anaerobic components in each exercise session [30].

Only in the 3<sup>rd</sup> session (week 1), did the maximal HR present values below the high intensity range (PWC170). Importantly, unstructured AVGs revealed the same decrease in this session but with lower magnitude. This may be related to acute adaptations of the cardiovascular system in the 1<sup>st</sup> week of training. In session 4 (the beginning of the 2<sup>nd</sup> week), a fall of HR responses were noted in both groups. This phenomenon may be observed in sedentary individuals after initiating systematic physical activities [31, 32]. The authors' hypothesis is that these variations should be due to decreased vagal stimulation, characterized by sympathetic and parasympathetic reorganization, regardless of the exercise intensity level [33].

Structured AVGs are able to promote progressive exercise intensities until the end of the training period. This effect was not discovered in the unstructured play, owing to the absence of the stimulus making the game more intensive and therefore more complex. In this regard, according to the ACSM [24], structured AVGs are more effective in promoting progression of the exercise intensity. However, as the structured game (Nike Kinect Training) is an activity virtually controlled through periodization elements of physical training, the intensity increment can produce more long-lasting cardiovascular benefits [34]. This reflects the importance of considering such factors when prescribing or using AVGs.

Similarly to HR, significant differences were observed between the AVGs in the 14<sup>th</sup> session for MET and EE. Some of these findings were expected, considering that the mathematical models applied to derive equations used HR as a variable in the calculation. However, the authors' intention was to assess the possibility of development and identification of EE modifications by doubly indirect models. This hypothesis was confirmed. The direct and indirect method analyses did not reveal statistically significant differences (unstructured AVGs: 2,1 ml/kg/min; structured AVGs: 1,3 ml/kg/min). In practical terms, this means a medium error of 0,75 kcal with unstructured AVGs and 0,46 kcal with structured

AVGs of differences analysed between the direct and indirect form.

In this sense, increases in the HR response reflect greater muscle activation and consequently also effort intensities [35]. Structured AVGs aim at functional activities such as stationary running, resistance exercises with isometrics, and also stretching activities, alternated in daily and weekly sessions automatically by the game itself. The study showed that these activities provided higher responses of HR, EE, and METs.

Indeed, there are few studies in the literature that demonstrate the actual metabolic adaptations in response to functional training. However, a previous study showed that physical training by functional resistance exercise promoted increases in muscle strength regardless of hypertrophy level [36]. This may explain, at least in part, the major neurological stimulation provided by these activities, also reflecting metabolic gains referring to the morphological adaptations in energy transmission systems. Thus, practically, structured AVGs promoting an exertion of ~200 kcal/session, if used every day, as recommended by ACSM [24], will probably reach the energy equivalent (1200 kcal/week) enough to prevent weight gain. Obviously, the application of this tool depends on the motivation to play.

The motivation for practicing AVGs has been studied as a way to control the levels of participation and adherence to PA programs [23, 35, 37]. However, our research showed no significant differences between the two AVG groups. Two main reasons for these findings may be hypothesized. Firstly, the scale used in the study, in line with previous studies, was initially developed to assess post-surgery pain levels in heart diseases [22], and to this date, there has been no validation and/or reliability study for physical activities with AVGs. Secondly, although the scale was found to be valid for these activities, scientific criteria related to its reproducibility and use in experimental studies in the medium- and long-term perspectives need to be identified. In short, if a participant wanted to play an AVG in a long term, their motivations did not differ in the AVG groups (Figure 4).

The limitations of this investigation include the fact that we used a sample of only young adult males. Research has shown that men and women have different exercise motivations [38] and attitudes towards video gaming. These differences may result in different exercise intensities during a game and subsequently different changes in peak workload and AE. In addition, the current study referred to a single structured and unstructured AVG only. Previous research has proved that not all games produce the same physical effort response [39, 40] or the same affective response [27]. Future research is needed to test the effectiveness of a broad range of structured and unstructured AVGs, as well as different combinations of games in order to optimize the health benefits induced by AVGs.



## Conclusions

The obtained data suggest that structured and unstructured AVGs provide a similar increase in average HR response and EE in young adults during 6 weeks. However, the structured AVGs showed higher values of these parameters. In addition, although motivation is an element that may distinguish unstructured and structured AVGs acutely, no differences between the AVGs were observed in a long-term analysis. This may suggest that the volunteer participation in these activities is similar in young adults. Finally, the indirect measurements present efficacy to analyse the AVG physical effort intensity during the sessions.

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