African Educational Research Journal
Vol. 11(3), pp. 452-459, September 2023
DOI: 10.30918/AERJ.113.23.070
ISSN: 2354-2160
Full Length Research Paper

Using combative and imitative active video games to increase the physical activity levels of university students on campus

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Accepted 1 September, 2023.

ABSTRACT

This study aimed to investigate the effects of combative and imitative active video games (AVGs) on the physical activity levels of university students on campus. University students (n = 10; mean age: 20.30 ± 1.57 years), participated in this study. Measurements were taken from each participant at two separate time points on a university campus. During these visits, the physiological responses were recorded for two AVGs and resting conditions for measurement of physical activity level. The AVGs were randomly played for 15 minutes using an Xbox One device on the university campus. Physiological responses were measured continuously using the computerized, breath-by-breath analysis system, also the heart rate was recorded continuously. Data were analyzed using a one-way repeated measures ANOVA. The findings demonstrate that active video imitative and combative games significantly increased physiological responses, the energy expenditure from 0.019 ± 0.002 (rest) to 0.102 ± 0.019 and 0.131 ± 0.017 $kcal.kg^{-1}.min^{-1}$, respectively. The MET values of games (imitative: 5.937 ± 1.03; combative: 7.547 ± 0.94) were significantly higher than the rest (1.120 ± 0.11). The HR values significantly increased from 72.4 ± 9.96 $beat.min^{-1}$ for rest to 132.2 ± 21.10 $beat.min^{-1}$ for the imitative game, and 153.1 ± 19.76 $beat.min^{-1}$ for the combative game. The highest physiological responses were determined for active video combative games which were significantly higher than active video imitative game responses ($p < 0.01$) and rest ($p < 0.001$). In conclusion, both combative and imitative AVGs, which can be integrated into campus and physical education classes, could serve as effective tools for increasing the physical activity levels of university students.

Keywords: Exergames, game structure, game playability, physical education, campus activity.

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INTRODUCTION

The World Health Organization (WHO) has indicated that physical inactivity ranks as the fourth most significant contributor to global mortality, constituting 6% of the global mortality rate (Aygün and Çakır-Atabek, 2018; WHO, 2020). It is acknowledged for its connection with risk factors for various chronic illnesses, including diabetes, cardiovascular diseases, and cancer (Barlow and Chang, 2007). Additionally, Amati et al. emphasize that insulin resistance is not merely a consequence of aging but is rather linked to obesity and physical inactivity. Insufficient physical activity not only leads to physical health complications but also negatively impacts mental well-being (Mokdad et al., 2004). Moreover, research has indicated that even brief periods of physical inactivity can contribute to metabolic and vascular disorders (Hamburg et al., 2007). A sedentary lifestyle is at the forefront of non-infectious disease-related deaths worldwide, causing around 3.2 million fatalities each year. It has been highlighted that 31% of individuals aged 15 and above globally do not engage in sufficient physical activity (Aygün and Çakır-Atabek, 2018; WHO, 2020).

Physical activity is defined as involving specific bodily movements that demand higher energy expenditure compared to a sedentary state. A higher level of physical activity is linked to a reduced risk of developing diseases (Warburton et al., 2006). Thus, in modern times, physical activity stands as a crucial factor in safeguarding health against conditions such as obesity, diabetes, and cardiovascular disorders (Garber et al., 2011). Adults are recommended to engage in moderate-intensity exercise for 30 minutes per day, five days a week. This regimen generally results in an energy expenditure ranging from approximately 5 to 7 Metabolic Equivalent (MET) (Garber et al., 2011). To maintain good health and prevent diseases associated with an inactive lifestyle, individuals need to integrate exercise into their daily routines. While technology often contributes to a sedentary lifestyle and subsequent health problems, it also provides opportunities to cultivate healthy habits.

Technology-based E-sports, exergames, and active video games are currently highly popular. Billions of people are interested in video and computer games. Video games can be categorized into two groups: sedentary (passive) video games and active video games (AVGs). Active video games, also known as exergames, offer a beneficial alternative to physical activity, particularly in mitigating the negative effects of a sedentary lifestyle. Active video games can increase participation in physical activity. Various AVG consoles are available on the market. Microsoft Xbox Kinect, Sony Play Station – Move, and Nintendo Wii are among the most preferred and well-known AVG systems. Xbox Kinect stands out as the only console among these that can be operated interactively without the use of a physical device (Kamel Boulos, 2012). With the rise in game console usage, a noticeable trend has emerged where individuals allocate their leisure time to playing video games. Reports reveal that video gaming is a pastime in 67% of U.S. households, with individuals spending an average of 8 hours per week on these games (Aygün and Çakır-Atabek, 2018). Given the interest of young adults in video games, AVGs can serve as an excellent way to encourage involvement in physical activity at university and at home (Aygün and Çakır-Atabek, 2022).

It has been noted that most studies conducted with AVGs correspond to light to moderate physical activity (1.5 < MET < 3 or 3 < MET < 6), similar to brisk walking (Canabrava et al., 2018; Clevenger and Howe, 2015; Monedero et al., 2014; O'Donovan et al., 2012). Nevertheless, recent studies have shown that some AVGs meet vigorous physical activity levels (MET > 6), similar to running (Çakir-Atabek et al., 2020; Aygün and Çakır-Atabek, 2022). The latest research findings have demonstrated that engaging in physical activity by playing active video games meets the recommendations for both high-intensity (>6 MET) and low/moderate-intensity physical activity (<6 MET) set by the American College of Sports Medicine (ACSM). Particularly young individuals, like university students, allocate more time to playing computer games and spend extended periods in front of screens. Therefore, AVGs can serve as an alternative exercise model aiming to increase individuals' levels of physical activity and thus cope with sedentary-related diseases. However, it is of utmost importance to acknowledge that factors such as the demographics of AVG users (including age, gender, physical fitness level, and skill proficiency), the console's capacity to detect full-body movements, and the nature of the chosen AVGs (such as dance, combat, yoga) can significantly impact elicited physiological responses (Aygün and Çakır-Atabek, 2022).

Particularly, the physiological effects of AVGs that are highly favored by users are examined in the literature. However, studies investigating the physiological effects based on the structures of these games are quite scarce in the literature. Particularly, the determination of physiological responses in imitative movement video games, defined as Imitative Active Video Games (IMAVG), such as dance games where players replicate the movements of avatars on the screen, and freedom of movement video games, referred to as Combative Active Video Games (CAVG), like fighting games where players can execute desired movements within a free-world platform against opponents' unpredictable actions, is crucial. This is not only important for comprehending the physiological reactions of games structured similarly but also for anticipating the physiological responses of these games.

Hence, the objectives of the current study were to investigate the effects of IMAVG and CAVG on the physical activity levels of university students on campus. In relation to this aim, the hypotheses of this study are as follows: (I) IMAVG and CAVG will meet the recommended levels of physical activity intensity. (II) The physiological responses of IMAVG and CAVG will be higher compared to resting values. (III) The physiological responses of CAVG will be higher than those of IMAVG.

MATERIALS AND METHODS

Participants

University students (n = 10) volunteered to participate in this study. A priori sample size calculation was conducted using G*Power, version 3.1.9.2, University of Kiel, Germany, for one-way repeated measures analysis of variance (ANOVA). An effect size of 0.5, power of 0.80, one group, and three measurements (rest, IMAVG and CAVG) were considered. Based on these criteria, a minimum of 9 participants were required for the study. The main inclusion criteria were participation without any medical, cardiovascular, metabolic, and respiratory disorders. At the outset of the study, all volunteers were informed about the potential experimental risks and their right to withdraw from the study at any time. The study protocol adhered to the ethical guidelines of the 1975 Declaration of Helsinki and the study was approved by the Ethics Committee of Eskişehir Technical University.

Anthropometric data collection

Firstly, anthropometric data were collected from all participants. A wall-mounted stadiometer (Holtain, UK) was used to measure barefoot standing height to the nearest 0.1 cm. Body mass (± 0.05 kg) was measured using a bioelectrical impedance analyzer (Tanita MC-180-MA, Japan). Body mass index was calculated as the body mass (kg) divided by height squared (m^2).

Active video games

AVG_Just Dance was selected for IMAVG, while

AVG_Fighter within AVG was chosen for CAVG. IMAVG and CAVG were each played for 15 minutes on non-consecutive days, separated by at least 48 hours, in random order. AVG trials were conducted using an Xbox One (Microsoft, USA) device. This device was chosen due to its availability of various AVGs with distinct features, allowing gameplay without the need to physically touch anything. Physiological variables were continuously monitored during the AVG sessions.

Resting condition

Physiological measurements during the resting condition were conducted randomly before one of the active video games. Participants lay in a supine position for 20 minutes, with mean values from the last 5 minutes of measured variables utilized in the analyses (Çakir-Atabek et al., 2020).

Measures

Measurements were taken from each participant at two separate time points on the university campus. During these visits, physiological variables were measured for two different active video games (AVG_ Just Dance and AVG_ Fighter Within) and a resting condition. The active video games were played randomly. Additionally, the resting measurement was randomly conducted before one of the active video games.

Calculation of examined physiological variables

Oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were continuously measured using the computerized breath-by-breath analysis system Master Screen-CPX (Care Fusion, Germany). The system was calibrated according to local air conditions, gas volume, and gas contents prior to testing sessions. Using Equations 1 and 2, energy expenditure (EE) and metabolic equivalent (MET) were calculated (Riebe, 2018). Heart rate (HR) was continuously recorded using a Polar chest band fixed to the participant's chest and a Polar brand S810i pulse watch (Polar Electro, Finland). HR data were downloaded from the watch using Polar software. Maximum HR (HRmax) and percentage of HRmax (HRmax%) were calculated using Equations 3 and 4, respectively (Riebe, 2018).

$$EE\ (kcal.kg^{-1}.min^{-1}) = (3.9 \times VO_2 + 1.1 \times VCO_2)\ /\ \text{weight of the individual (kg)} \quad (1)$$

$$MET = VO_2\ (ml.kg^{-1}.min^{-1})\ \text{of the individual} / 3.5 \quad (2)$$

$$HR\ max = 220 - age \quad (3)$$

$$HRmax\ \% = (HR_{condition} * 100)/HRmax \quad (4)$$

Statistical analysis

All statistical analyses were performed using SPSS version 23.0 for Windows (Statistical Package for the Social Sciences, SPSS Inc.). Results are presented as the mean ± standard deviation (SD). The normal distribution of data was assessed using the Shapiro-Wilk test. The effects of active video games on the examined physiological variables were analyzed using a one-way repeated measures ANOVA. Mauchly's sphericity test was employed to check for sphericity. In cases where the F-test statistic was significant ($p < 0.05$), Bonferroni post-hoc methods were applied for multiple pairwise comparisons. Power analysis (1-β) was conducted, and effect sizes were calculated as partial eta-squared (η_p^2). A significance level of $p < 0.05$ was considered statistically significant.

RESULTS

The demographic data of participants are presented in Table 1. In addition, the examined physiological variables are presented in Figures 1, 2, 3, and 4. The results of repeated measures ANOVA show that EE, MET, HR, and HRmax% values were significantly different between conditions ($F = 179.50$, $F = 193.48$, $F = 115.76$, $F = 115.17$, respectively; $p < 0.001$), additionally, the statistical power (1-β) was determined as 1.000 for all examined variables, and the effect sizes calculated as the partial eta-squared (ηp^2) were determined higher than 0.95 for EE and MET, and higher than 0.92 for HR and HRmax%. The findings demonstrate that AVGs significantly increased the EE ($kcal.kg^{-1}.min^{-1}$) from 0.019 ± 0.002 to 0.102 ± 0.019, and 0.131 ± 0.017 $kcal.kg^{-1}.min^{-1}$ (Figure 1). The MET values of AVGs (AVG_Just dance: 5.937 ± 1.03; AVG_Fighter within: 7.547 ± 0.94) were significantly higher than the MET value of the rest condition (1.120 ± 0.11) (Figure 2). The HR ($beat.min^{-1}$) values significantly increased from 72.4 ± 9.96 $beat.min^{-1}$ for rest condition to 132.2 ± 21.10 $beat.min^{-1}$ for AVG_Just dance, and 153.1 ± 19.76 $beat.min^{-1}$ for AVG_Figher within (Figure 3). The HRmax% was determined as 66.21 ± 10.6 for AVG_Just dance, and 76.66 ± 9.9 for AVG_Figher within. These findings show that AVGs significantly increased the values of HRmax% compared to rest condition (HRmax% for rest: 36.24 ± 4.9) (Figure 4). The highest physiological responses of EE, MET, HR, and HRmax% were determined for AVG_Fighter which were significantly higher than AVG_Just dance responses ($p < 0.01$) and rest ($p < 0.001$) (Figures 1, 2, 3 and 4, respectively).

Table 1. The mean ± SD values of demographic variables of participants.

Variables (n = 10)	Mean ± SD
Age (years)	20.30 ± 1.57
Height (cm)	174.40 ± 4.03
Body Mass (kg)	72.00 ± 9.35
Body Mass Index ($kg.m^{-2}$)	23.70 ± 3.31
Heart Rate maximum ($beat.min^{-1}$)	199.70 ± 1.56

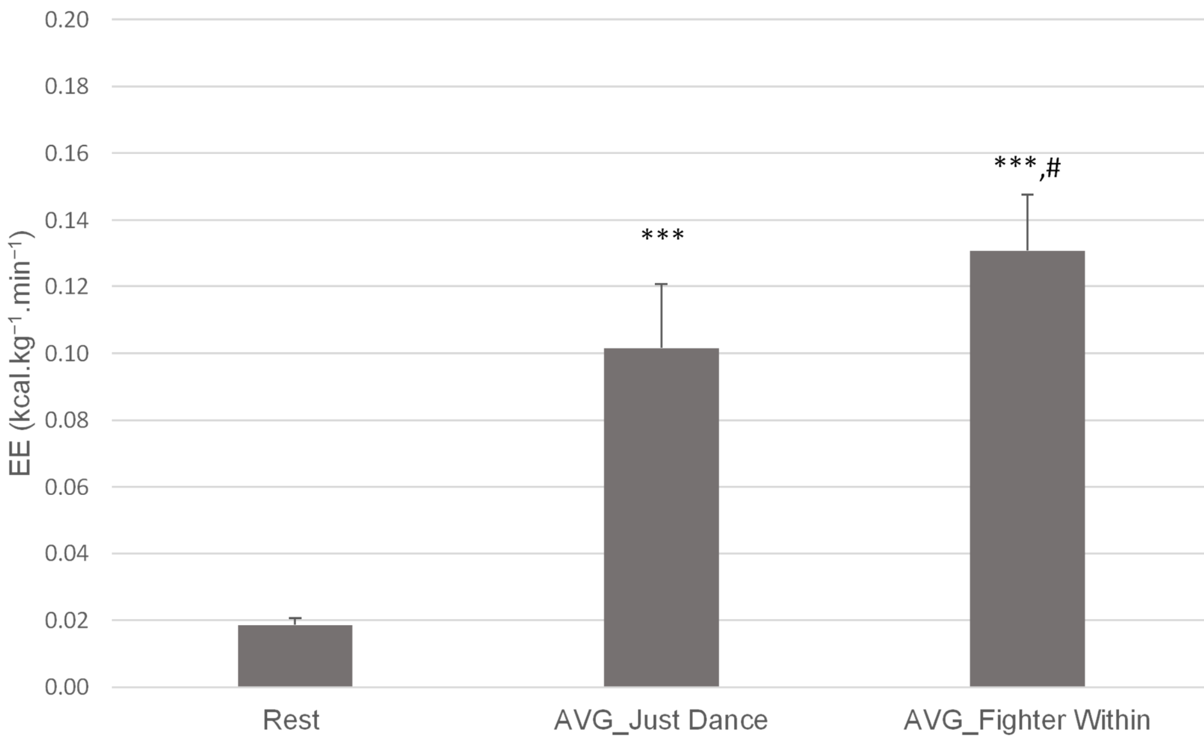

Figure 1. The energy expenditure (kcal.kg^{-1}.min^{-1}) values of participants for different conditions. AVG: active video game; *** $p < 0.001$ significantly different from rest; # $p < 0.01$ significantly different from AVG_Just dance.

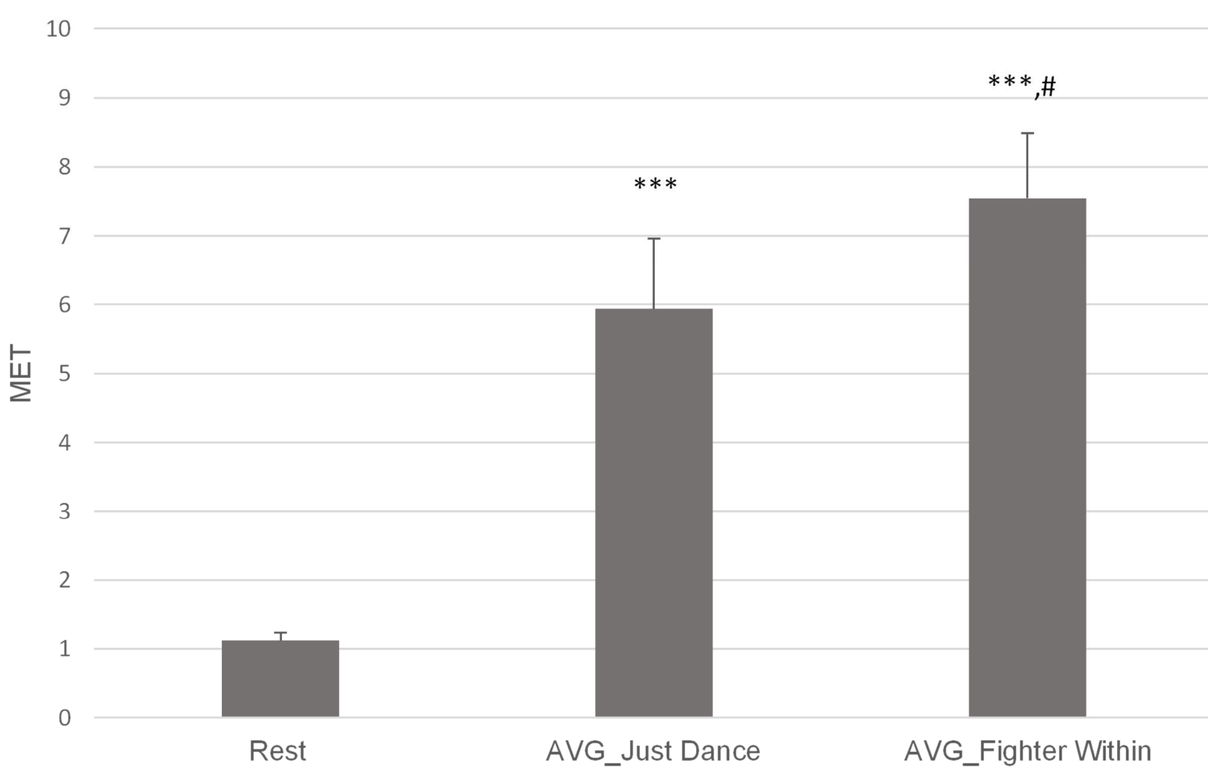

Figure 2. The metabolic equivalent (MET) values of participants for different conditions. AVG: active video game; *** $p < 0.001$ significantly different from rest; # $p < 0.01$ significantly different from AVG_Just dance.

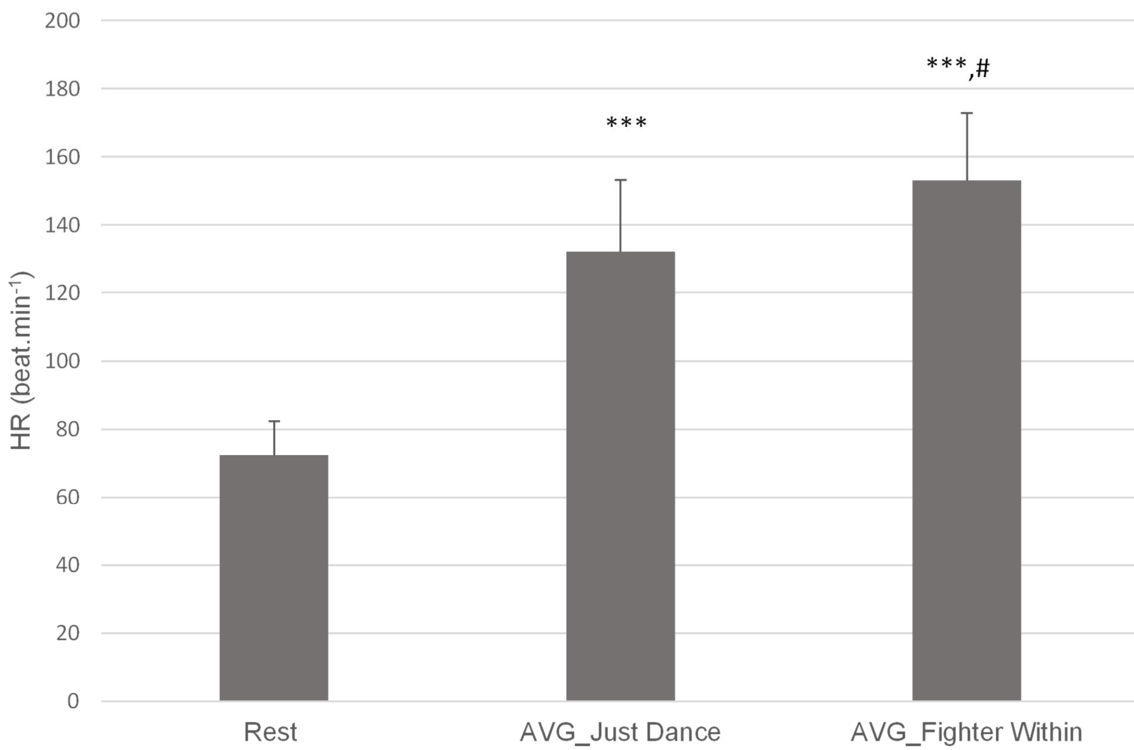

Figure 3. The heart rate (beat.min^{-1}) values of participants for different conditions. AVG: active video game; *** $p < 0.001$ significantly different from rest; # $p < 0.01$ significantly different from AVG_Just dance.

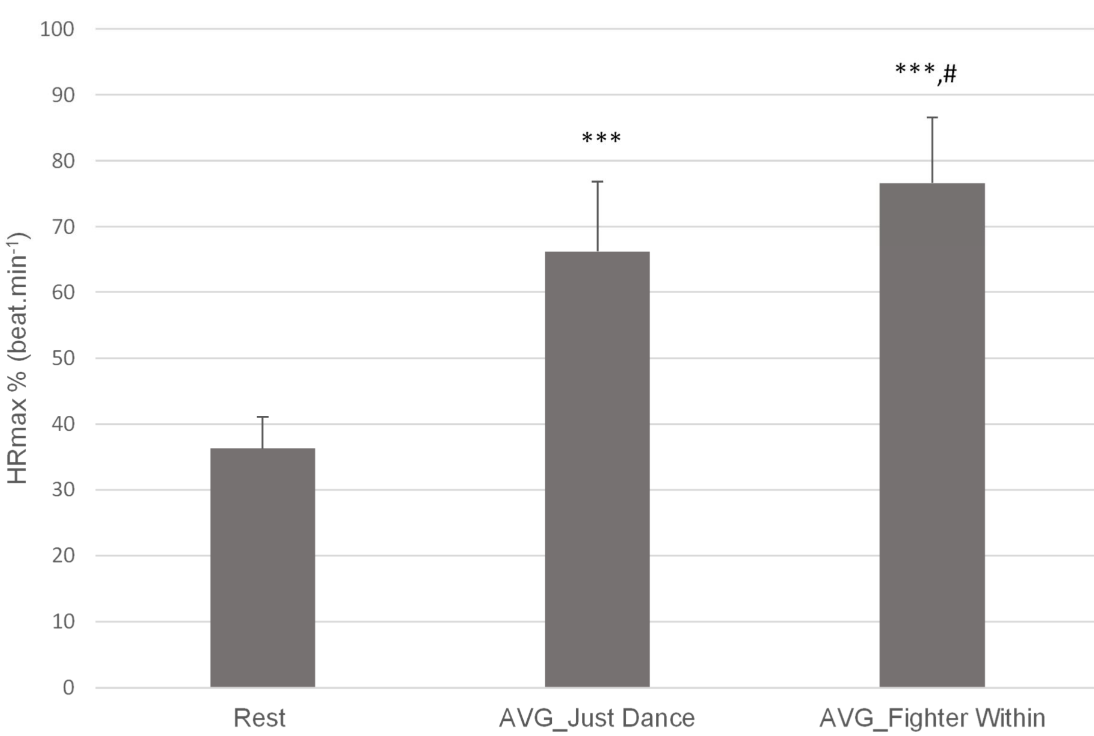

Figure 4. The percentage of heart rate maximum (beat.min^{-1}) values of participants for different conditions. AVG: active video game; *** $p < 0.001$ significantly different from rest; # $p < 0.01$ significantly different from AVG_Just dance.

DISCUSSION

The current study was to investigate the effects of IMAVG and CAVG on the physical activity levels of university students on campus. In relation to this aim, the hypotheses of this study are as follows: (I) IMAVG and CAVG will meet the recommended levels of physical activity intensity. (II) The physiological responses of IMAVG and CAVG will be higher compared to resting values. (III) The physiological responses of CAVG will be higher than those of IMAVG.

The main findings of this study demonstrated that the examined AVGs' physiological responses meet the recommended physical activity levels (IMAVG = 5.937 MET; CAVG = 7.547 MET). Values of EE, MET, HR, and HRmax% in AVGs significantly increased compared to the resting condition, and these values differed significantly between CAVG and IMAVG in university students. The highest values of EE, MET, HR, and HRmax% were observed for CAVG.

Early investigations in this field have encompassed comparisons between AVGs and passive video games, as well as comparisons against sedentary conditions such as rest and television watching (Clevenger and Howe, 2015; Graves et al., 2010; Marks et al., 2015; O'Donovan et al., 2012; O'Donovan and Hussey, 2012; Scheer et al., 2014; White et al., 2011). Moreover, numerous studies have been dedicated to contrasting different AVGs with each other (Clevenger and Howe, 2015; Lanningham-Foster et al., 2009; Noah et al., 2011; O'Donovan and Hussey, 2012). Recent research has expanded to include comparisons of various AVG consoles (Marks et al., 2015; O'Donovan et al., 2012; Scheer et al., 2014) and assessing AVGs against classical exercise routines (Aygün and Çakır-Atabek, 2022; Çakır-Atabek et al., 2020; Devereaux, 2012; Graves et al., 2010; White et al., 2011). Investigations involving diverse participant groups have notably encompassed the elderly, disabled, and obese individuals (Seamon et al., 2017; Staiano et al., 2017). However, there is a distinct lack of studies that compare the physiological effects of AVGs utilizing Xbox Kinect in terms of gameplay styles and game characteristics.

Physiological parameters investigated in the context of AVGs have primarily focused on variables such as VO_2, HR, and EE (Aygün et al., 2018; Clevenger and Howe, 2015; Devereaux, 2012; Graves et al., 2010; Marks et al., 2015; O'Donovan et al., 2012; White et al., 2011). Research has indicated that VO_2 consumption during AVGs notably exceeds that observed during sedentary conditions (including rest, television watching, and passive games) (Aygün and Çakır-Atabek, 2022; Çakır-Atabek et al., 2020; Clevenger and Howe, 2015; Graves et al., 2010; O'Donovan et al., 2012; O'Donovan and Hussey, 2012; Scheer et al., 2014; White et al., 2011). The findings of this study are consistent with the findings of the mentioned studies. Similar to the observations related to VO_2, the demand for EE AVGs has been demonstrated to be notably higher than that during sedentary conditions (Clevenger and Howe, 2015; Graves et al., 2010; O'Donovan et al., 2012; O'Donovan and Hussey, 2012; Scheer et al., 2014; White et al., 2011). Clevenger and Howe (2015) conducted a comparison between Xbox Kinect AVGs and passive video games, resulting in a significant increase in EE among adolescents (n = 58; age range: 8 to 17 years) after playing AVGs for 6 to 10 min. In a separate investigation, a comparative analysis of active video boxing and dancing games highlighted a significant increase in HR during the Xbox Kinect-based boxing game (Marks et al., 2015). Notably, it has been established that the physiological reactions to AVGs can be influenced by multiple variables, including the gaming console model, player count, music tempo, and inherent game attributes (Marks et al., 2015).

Clevenger et al. (2015) conducted a study involving 6 to 10 min of playing AVGs, specifically Dance Central and Zumba. During Zumba AVG, an oxygen consumption of 9.1 L/min and a heart rate of 128.5 beats per minute were recorded. Dance Central AVG, on the other hand, resulted in an oxygen consumption of 10.2 L/min and a heart rate of 135.1 beats per minute. Marks et al. (2015) engaged participants (8 males and 7 females, mean age = 21.3 ± 1.4 years old) in 10-minute sessions of Kinect Just Dance. Kinect Just Dance resulted in an oxygen consumption of 13.7 ml/kg/min, an energy expenditure of 4.1 kcal/kg/h, and a heart rate of 111.5 beats per minute. In the study conducted by Aygün et al. (2018), participants engaged in a 15-minute session of AVG Dance Central 3, resulting in a recorded oxygen consumption of 23.20 mL/kg/min, corresponding to a metabolic equivalent (MET) of 6.63. Additionally, an energy expenditure of 7.26 kcal/min, a heart rate of 138.38 beats per minute, and a heart rate equivalent to 69.23% of their maximum heart rate were observed. The findings of this study have demonstrated results that are similar to or higher than the existing literature findings. In this study, the physiological results of the played IMAVG showed an EE 0.102 $kcal.kg^{-1}.min^{-1}$, corresponding to a MET of 5.937. Additionally, a heart rate of 132.2 beats per minute and a heart rate equivalent to 66.21% of their maximum heart rate were observed.

In a study conducted by O'Donovan and Hussey (2012), participants (18 males and 10 females, mean age = 22 years old), engaged in 15 min of Wii boxing AVG, resulting in a recorded VO_2 consumption of 13.5 ml/kg/min and energy expenditure of 305.5 kJ/15 min. Additionally, a metabolic equivalent of 3.2 MET and a heart rate equivalent to 58% of their maximum heart rate were observed. In another investigation by O'Donovan et al. (2012), a 10-minute session of Wii Sports Boxing yielded an oxygen consumption of 13.3 ml/kg/min and an energy expenditure of 4.9 kcal/min. This corresponded to a MET value of 3.1 and a heart rate of 107 beats per minute. Marks et al., (2015) engaged participants (8 males and 7 females, mean age = 21.3±1.4 years old) in 10-minute sessions of Kinect Boxing exhibited an oxygen consumption of 15.3 ml/kg/min, an energy expenditure of 4.6 kcal/kg/hr, and a heart rate of 124.9 beats per minute. In a study by White et al. (2011) involving 26 boys (mean age = 11.4 ± 0.8 years) playing Wii boxing, an oxygen consumption of 20.2 ml/kg/min, energy expenditure of 411 J (kg/min), and a heart rate of 140 beats per minute were observed.

Scheer et al. (2014) conducted a study involving 10 males (mean age = 20.1 ± 0.4 years) and 9 females (mean age = 19.8 ± 0.3 years) engaging in 8-minute sessions of Kinect boxing. This resulted in an oxygen consumption of 10.6 ml/kg/min, energy expenditure of 4.2 kcal/min, and a heart rate of 119.3 beats per minute. For Move gladiatorial combat, an oxygen consumption of 9.6 ml/kg/min, energy expenditure of 3.8 kcal/min, and a heart rate of 120.2 beats per minute were recorded. In a study by Chaput et al. (2015) involving 19 obese adolescent boys (mean age = 14.5 ± 0.8 years), 60 minutes of active video game - boxing yielded an energy expenditure of 370 ± 4 kcal and a heart rate of 119 ± 1 beats per minute. The findings of this study have demonstrated results that are similar to or higher than the existing literature findings. In this study, the physiological results of the played CAVG show an EE 0.131 $kcal.kg^{-1}.min^{-1}$, corresponding to a MET value of 7.547. Additionally, an observed heart rate of 153.1 beats per minute and a heart rate equivalent to 76.66% of their maximum heart rate. Considering the findings of this study and the literature, CAVG like boxing and fighting, it can be thought that the physiological responses of AVGs in the style of CAVG may be similar to the physiological responses due to the AVGs' gameplay structure. Additionally, it should be taken into account that they may also differ from AVGs with different gameplay structures.

Conclusion

Physical inactivity and sedentary behavior are increasing, especially among adolescents and university students, which also increases the risk of health problems. Active video games that do not require complex facilities can be positively utilized, especially considering the interest of university students in screen-based activities, to increase physical activity levels and reduce sedentary behaviors. They can serve as an enjoyable alternative solution to the rise of inactivity and sedentary behavior, both on campus and in physical education classes.

This study has found that the imitative and combative active video games examined within its scope meet the physical activity recommendations set forth by leading health organizations. Combative active video games, designed with scenarios involving unrestricted movement and a competitive framework, might lead to higher levels of physical activity intensity compared to imitative games. Furthermore, this study proposes that both tested games could effectively serve as tools to increase the physical activity levels of university students on campus. Additionally, these AVGs can also be integrated into physical education classes.

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Citation: Aygün, C. (2023). Using combative and imitative active video games to increase the physical activity levels of university students on campus. African Educational Research Journal, 11(3): 452-459.