

## Original Research

# Cardiovascular Responses, Physical Activity Intensity, and Enjoyment Level of Nintendo Switch™ Exergaming, Comparing Different Tempos and Playing Modes: A Pilot Study

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### ABSTRACT

**Background:** Physical activity (PA) has been associated with multiple health benefits. However, the global population does not meet the PA recommendations. Virtual reality exergaming (VR EXG) can become an option to increase PA because it is fun, relatively easy to access and affordable through popular commercial devices.

**Aim:** To investigate the immediate cardiovascular responses (blood pressure, heart rate), quantification of PA intensity (percentage of maximum heart rate (%HRmax), Borg's rating of perceived exertion (RPE), and the level of enjoyment using visual analog scale (VAS) while playing VR EXG.

**Material and Methods:** Fifteen healthy men (aged 31.87±3.14 years old, body mass index 23.77±2.47 kg/m<sup>2</sup>) undergone three "Fitness Boxing" Nintendo Switch™ playing modes in the same order: (1) single player-normal tempo, (2) single player-fast tempo and (3) versus. During playing, participant's HR was monitored using Polar H10 heart rate sensor. Blood pressure was measured before and after playing. Borg's RPE and VAS were collected after playing.

**Results:** Our results showed significant heart rate and systolic blood pressure increase ( $p = 0.001$ ) in all three playing conditions, whereas diastolic blood pressure was relatively constant ( $p > 0.05$ ). The Borg's RPE were in 12-13 range (moderate) and %HRmax range between 72- 81% (vigorous). The enjoyment level was found greatest in versus mode compared to other playing modes.

**Conclusion:** VR EXG Nintendo Switch™ "Fitness Boxing" can elicit immediate cardiovascular responses and provides an enjoyable moderate to vigorous PA intensity in healthy male adults, and can be used to meet the weekly PA recommendations.

**Keywords:** *boxing, cardiovascular responses, enjoyment level,*

## Introduction

Physical activity is associated with improvement in physical functions, mental health, cognition, sleep quality, quality of life, as well as reducing the risk of diseases, obesity, depression, and anxiety.<sup>1,2,3</sup> However, 23% adult and 81% adolescent (11-17 years old) worldwide, do not meet the defined physical activity recommendations.<sup>3</sup> Despite knowing the potential for its preventive and therapeutic effects, 31% of the total population remain sedentary<sup>4</sup>, not motivated to adopt a healthy lifestyle (including physical activity), 21% of the population do not intend to start physical activity, while the other 36% have the intention but face difficulty in changing the sedentary behavior.<sup>5</sup> Therefore, other strategies are needed to make physical activity more attractive and motivating to increase compliance and continuity that encourages individuals to become more active physically.<sup>4</sup>

Virtual reality exergaming (VR EXG) can be an alternative option to increase physical activity level because it is fun, the technology is relatively easy to access and at affordable costs through popular commercial device (Nintendo Wii™, Xbox® Kinect).<sup>4,6,7,8</sup> Virtual reality (VR) is a term that describes interactive computer simulations that give the user an opportunity to participate in environments that look and feel similar to real-world events and objects.<sup>9</sup> Exergame (exercise game; exertion game) is a VR based exercise, and is defined as video games that use or require the physical movement of players beyond sedentary conditions with components of strength, balance, and flexibility.<sup>10</sup> VR EXG can be used in various places (hospitals, homes, schools, elderly care institutions), and has been extensively studied for its use to increase physical activity, prevent obesity, reduce pain, improve motor function, cognitive

function, postural control, balance and gait, in various age groups and patient conditions (stroke, cerebral palsy, traumatic brain injury, spinal cord injuries, Parkinson's disease, multiple sclerosis, burns).<sup>11,12,13,14,15,16,17,18</sup> Kwan and Brayan<sup>19</sup> stated that pleasant feelings after doing exercise can give positive affective responses and cause an individual to be physically active and maintain physical activity in longer period. The degree of liking/enjoyment contributes to the compliance of the individual training regimen, therefore, VR EXG can increase the likelihood of achieving general health benefits through regular physical activity<sup>4</sup>.

Various VR EXG studies around the world use popular commercial game consoles such as the Nintendo Wii™, Xbox® Kinect®.<sup>4,6,7,11,13,14,16,18</sup> Nintendo Switch™<sup>20</sup> is the latest generation game console from Nintendo and is a hybrid video game console released to the public in March 2017. "Fitness Boxing"<sup>21</sup> is an exergame for the Nintendo Switch™ and was commercially marketed in December 2018. To the best of author knowledge, there has not been any study based on the Nintendo Switch™ console.

An understanding of physiological responses during physical activity is important to obtain training variables and produce strategies that can be used to increase compliance, prescribe rehabilitation programs, and ensure patient safety. This study aims to investigate the immediate responses of the cardiovascular system, quantification of the physical activity intensity, and the level of enjoyment while playing VR EXG "Fitness Boxing" Nintendo Switch™ in different tempos and playing modes in order to achieve standardize values of physiological responses as training parameters for unstandardized, limited customization of commercial video game.

## **Material and Methods**

Fifteen healthy men were recruited for this study using consecutive sampling from Department of Physical Medicine and Rehabilitation of dr. Soetomo hospital via instant messenger broadcast message. The participants were included in following criteria: (1) aged 21-39 years; (2) Body Mass Index (BMI) 18.5 - 29.9 kg/m<sup>2</sup>; (3) low to moderate classification based on the International Physical Activity Questionnaire (IPAQ) – Indonesian version<sup>22</sup>; (4) did not smoke, did not consume alcohol; (5) did not consume caffeine or energy drink, or drugs containing ephedrine 24 hours prior to data collection; (6) did not do strenuous activity/exercise 12 hours prior to data collection. The exclusion criteria were: (1) "yes" response to one item of the Physical Activity Readiness Questionnaire (PAR-Q)<sup>23</sup>; (2) suffer from illness or conditions that cause playing difficulties or affect the safety of the participants during data collection. Participants completed general health examination. The study was approved by Dr. Soetomo hospital ethic committee (1834/KEPK/II/2020) and all participants signed written informed consent.

This study was an experimental series with repeated measure design. All participants played VR EXG "Fitness Boxing" using Nintendo Switch™ video-game console in laboratory setting, conducted in motion and gait analysis lab of Physical Medicine and Rehabilitation Department of Dr. Soetomo Hospital. This platform was chosen because it is one of newest gaming console, specifically the successor of Nintendo Wii, which has been popularly used in wide area of rehabilitation research. The outcome parameters were heart rate, systolic and diastolic blood pressure, percentage of age-predicted maximal heart rate (% HRmax), Borg's rating of perceived exertion (6-20 scale)<sup>24</sup> and visual analog scale (VAS)<sup>25</sup> of enjoyment level.

Familiarization period of 3-5 minutes playing the video-game was carried out after brief explanation and demonstration of gameplay. Participants were told to wear comfortable clothes and shoes while playing. Before each session, systolic and diastolic blood pressure and heart rate were recorded after 10 minute rest in sitting position. Polar H10 sensors was used for heart rate measurement and monitoring. All Participants undergone 30 minutes of three playing conditions in the same order: (1) single player mode - normal tempo, (2) single player mode - fast tempo, and (3) versus mode (normal tempo) in two consecutive days. The first and second playing condition were done in first day of data collection, whereas versus mode were taken in the second day. In the first and second playing condition, participants played by himself, started with warm-up and then encouraged to follow virtual trainer instruction in terms of stance, upper and lower extremities movements (see figure 1). There were 6 exercise menu to choose consisted of the most basic punches: straight, hook and uppercut, which accumulated into 30 minutes total playing duration. Thirty minutes rest interval was provided to reset the participant's vital signs (heart rate and blood pressure) back to pre-playing condition. In the second day, after warmed-up, each participant played against human opponent in three minutes round with total accumulation playing duration of 30 minutes. Upon completion of each playing session, blood pressure was recorded in standing position within 30 seconds time frame, then the participants sat down and asked how hard was the playing session in 6-20 scale of Borg's RPE and how much participants enjoyed the playing session using VAS by making a mark on a horizontal line (from 0 – 100 mm); 0 = do not enjoy it at all; 100 = enjoy it very much. %HRmax was calculated from the highest heart rate recorded during playing (HRpeak) divided by age-predicted maximum heart rate (220 - age) times 100%. Moderate physical activity intensity

was classified as 64–76 %HRmax or 12-13 of Borg’s RPE, whereas vigorous physical

activity intensity was classified as 77–95 %HRmax or 14-17 of Borg’s RPE.<sup>24</sup>



**Figure 1. Participants playing “Fitness Boxing” using Nintendo Switch™ console while receiving audiovisual and tactile biofeedback during straight punch**

Outcome parameters were assessed for normality using Shapiro-Wilk tests. Data analysis by comparing the average values of heart rate, systolic and diastolic blood pressure before and after playing session were assessed using paired-t tests when the data normally distributed or Wilcoxon Signed Ranks test if the data obtained not normally distributed. Differences between playing sessions tempo (normal and fast), playing mode (single and versus), relative intensity (%HRmax, Borg’s RPE) and enjoyment’s VAS score were assessed using different tests taking into account of the normality test prerequisites. Repeated measure analysis of variance (with

Greenhouse-Geisser correction applied when sphericity was not met) was used if the data obtained are normally distributed. If the data obtained was not normally distributed, then Friedman test was used. All data analyses were performed using SPSS software version 23.

## Results

Fifteen healthy male adult participants met the criteria. No participants dropped out during the study. Table 1 shows the participants characteristic.

**Table 1. Participants Characteristic**

Characteristic	Mean ± Standard Deviation	Range
Age (years)	31.87 ± 3.14	26-36
Height (cm)	168.37 ± 8.06	156-183
Body mass (kg)	67.71 ± 11.18	51.5-88.3
Body mass index (kg.m <sup>-2</sup> )	23.77 ± 2.47	19.62-28.34

**Table 2. Outcome parameters**

Parameters		Single Player Mode		Versus Mode	p1	p2	p3	p4
		Normal Tempo	Fast Tempo					
HR (bpm)	Rest	82.33 ± 5.90	82.07 ± 6.15	82.67 ± 6.55	0.667 <sup>a</sup>	-	-	-
	Peak	159.33 ± 19.12	156.73 ± 22.48	148.47 ± 22.43	0.032 <sup>a*</sup>	0.297 <sup>c</sup>	0.064 <sup>c</sup>	0.022 <sup>c*</sup>
ΔHR (bpm)		77.00 ± 16.65	74.67 ± 18.94	65.80 ± 18.99	0.028 <sup>b*</sup>	0.231 <sup>d</sup>	0.061 <sup>d</sup>	0.019 <sup>d*</sup>
SBP (mmHg)	Pre	112.33 ± 6.78	113.67 ± 7.19	113.33 ± 8.17	0.595 <sup>a</sup>	-	-	-
	Post	140.00 ± 13.09	136.00 ± 13.52	135.33 ± 14.08	0.269 <sup>b</sup>	-	-	-
DBP (mmHg)	Pre	73.33 ± 6.17	72.67 ± 5.94	70.67 ± 7.99	0.368 <sup>a</sup>	-	-	-
	Post	70.00 ± 7.56	71.33 ± 8.34	70.00 ± 8.45	0.852 <sup>a</sup>	-	-	-
%HRmax		84.70 ± 10.20	83.07 ± 12.05	78.95 ± 12.07	0.034 <sup>a*</sup>	0.243 <sup>c</sup>	0.078 <sup>c</sup>	0.022 <sup>c*</sup>
Borg's RPE		13.00 ± 1.51	13.20 ± 1.42	12.60 ± 1.45	0.173 <sup>a</sup>	-	-	-
Enjoyment (mm)		72.27 ± 11.06	76.80 ± 11.89	81.00 ± 11.96	0.001 <sup>b*</sup>	0.022 <sup>d*</sup>	0.078 <sup>d</sup>	0.002 <sup>d*</sup>

Note: Data in mean ± standard deviation. Δ: delta. Pre-, before playing session; Post-, after playing session. <sup>a</sup>Friedman test, <sup>b</sup>repeated measure ANOVA test; <sup>c</sup>Wilcoxon signed ranks test; <sup>d</sup>pairwise comparison data of repeated measure ANOVA test; \*p < 0.05.

p1: difference of three playing conditions;

p2: difference between single player mode-normal tempo and fast tempo;

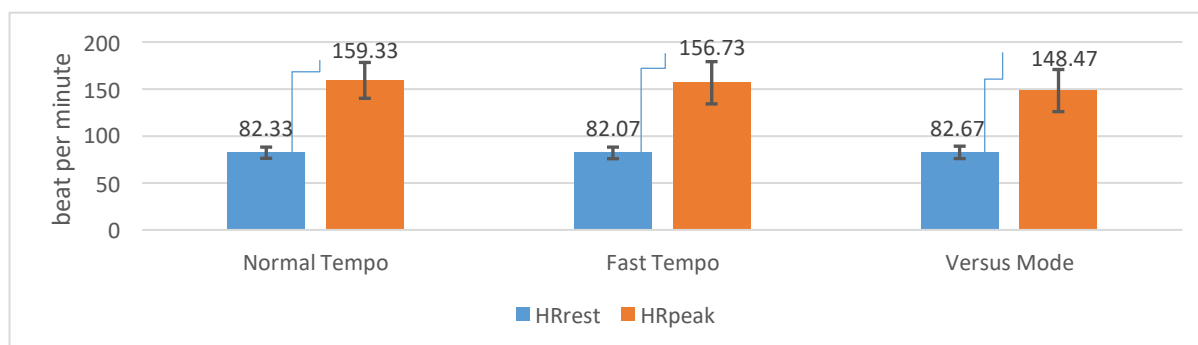
p3: difference between single player mode-fast tempo and versus mode;

p4: difference between single player mode-normal tempo and versus mode.

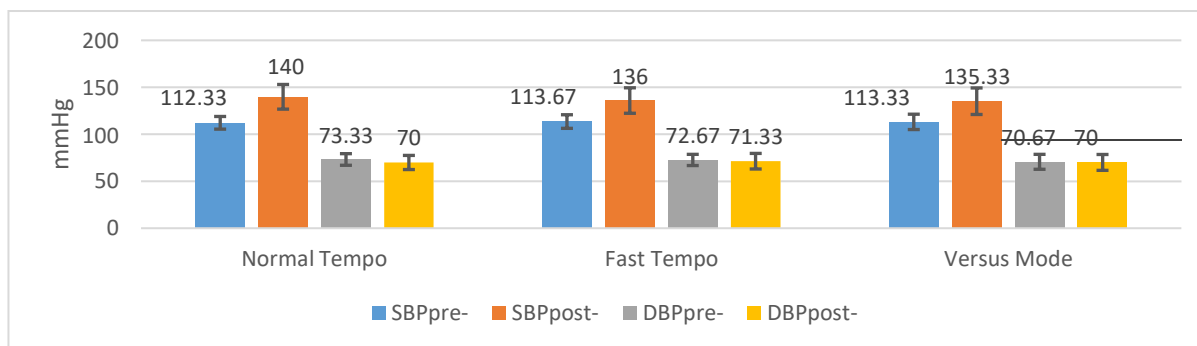
Abbreviation: HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure, %HRmax, percentage of age-predicted maximum heart rate; RPE, rating of perceived exertion.

The results of this study showed significant increase in heart rate of all three playing conditions ( $p = 0.001$ , see figure 2), and significant differences were obtained when playing normal tempo compared to versus mode on HRpeak ( $159.33 \pm 19.12 - 148.47 \pm 22.43$  bpm,  $p = 0.022$ ) and ΔHR ( $77.00 \pm 16.65 - 65.80 \pm 18.99$ ,  $p = 0.019$ ). There was significant difference ( $p = 0.001$ , see figure 3) on the increase in systolic blood pressure (pre- compared to post-playing) of all three playing conditions (normal tempo:  $112.33 \pm$

$6.78 - 140.00 \pm 13.10$ ; fast tempo:  $113.67 \pm 7.19 - 136 \pm 13.52$ ; versus mode:  $113.33 \pm 8.17 - 135.33 \pm 14.08$ ), without any significant difference between three playing conditions ( $p$  pre = 0.595;  $p$  post = 0.269). Diastolic blood pressure was relatively constant and there was no significant difference. Increased heart rate and systolic blood pressure were found to be higher at normal tempo compared to fast tempo and versus mode.



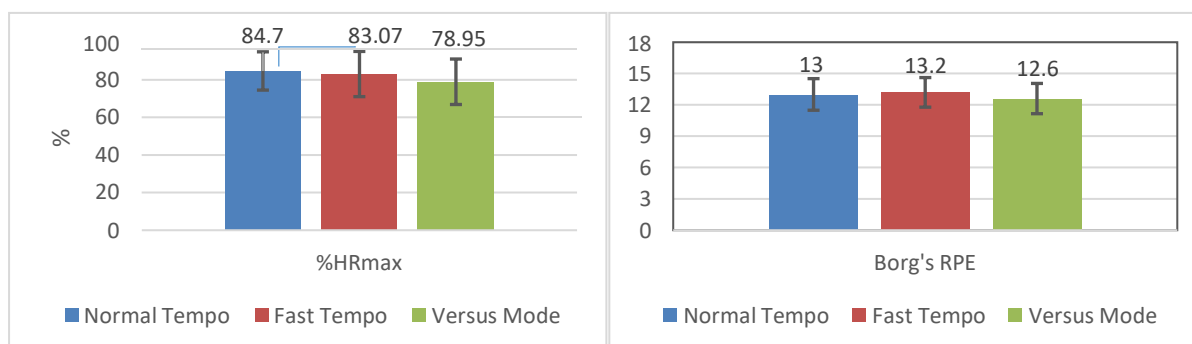
**Figure 2. Heart rate changes. \*p-value = 0.001**



**Figure 3. Blood pressure changes. \* $p$ -value = 0.001**

There was no significant difference ( $p = 0.173$ ) of the Borg's rating of perceived exertion (range 12-13), while there was a significant difference ( $p = 0.034$ ) in the %HRmax of the three playing conditions, between normal tempo ( $84.70 \pm 10.20\%$ ) and versus mode ( $78.95 \pm 12.07\%$ ) ( $p = 0.022$ )

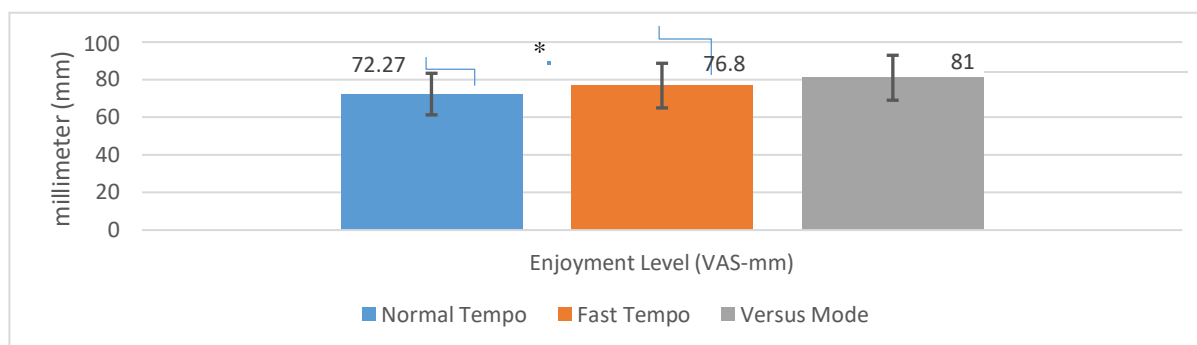
(see figure 4). These data are in line with findings from heart rate and systolic blood pressure changes. The physical activity intensity category based on the Borg's RPE is moderate, however, based on the %HRmax values, it is included in vigorous intensity category.



**Figure 4. Playing intensity comparison based on %HRmax and Borg's RPE. \* $p$ -value = 0.022**

The level of enjoyment range was 72 - 81 mm (VAS). The fast tempo single player mode ( $76.80 \pm 11.89$ ) was more fun than the normal tempo single player mode ( $72.27 \pm 11.06$ ) ( $p = 0.022$ ), and versus mode ( $81.00 \pm 11.96$ ) was more fun than the normal

tempo single player mode ( $p = 0.002$ ) (see figure 5). This is consistent with the hypothesis that multiplayer mode provides higher level of pleasure than the single player mode.



**Figure 5. Visual analog scale (VAS) of enjoyment level comparison. \* $p$ -value < 0.05**

## Discussion

To the best of authors' knowledge, this is the first study to assess immediate cardiovascular responses, relative intensity of physical activity, and enjoyment level while playing virtual reality exergame (VR EXG) "Fitness Boxing" using the Nintendo Switch™.

The results of this study indicate that playing VR EXG can increase heart rate and systolic blood pressure, which is also in accordance with previous studies.<sup>15,26,27</sup> Interestingly, increased heart rate and systolic blood pressure were found to be higher at normal tempo than fast tempo and versus mode. This can be caused by several factors. First, the participants had never played VR EXG and playing with normal tempo was the first playing session where the participants were still in the adaptation stage. The next session was playing with fast tempo and the last was versus mode. Over time, the participants became more skilled and more efficient in movement response in terms of energy expenditure (reducing whole body movement, focusing more on the upper limb movements). Second, in the normal tempo-single playing mode, the participants did six game menus and minimum of ten rounds of versus mode to reach 30 minutes duration. The number of game menus/rounds had an impact on the rest/inactivity periods between menus/rounds (loading process, preparation), so that there was decrease in

playing activity.

The fast tempo-single player mode is more fun than the normal tempo and versus mode is more fun than the normal tempo-single player mode. This is consistent with the hypothesis and reinforced by Peng and Crouse<sup>28</sup> research, that playing together (cooperation or competition), increased enjoyment level. This could encourage a person to be physically active, maintain physical activity in the long run and contribute to exercise regimen compliance.<sup>19</sup>

The relative intensity of playing VR EXG is categorized as moderate from the Borg RPE and vigorous based on the value of %HRmax. The results are similar to study by Wu et al.<sup>29</sup>, but in several other studies, the intensity of boxing exergames using Nintendo Wii and XBOX Kinect lies within mild to moderate category.<sup>26,30</sup> This difference in relative intensity between Borg's RPE and %HRmax can be caused by the fact that the Borg's RPE is more subjective and was obtained after playing, while the %HRmax is more objective because the heart rate was monitored continuously during playing. Another possibility was because playing EXG VR "Fitness Boxing" is fun, as stated by Perusek et al.<sup>31</sup> that participants do not consider VR EXG difficult or challenging because of the high level of pleasure. Zeng et al.<sup>15</sup> also suggests that the lower Borg RPE value is likely caused by pleasant feelings from a

playing experience that has never been done before. VR EXG intensity data "Fitness Boxing" meets ACSM and AHA recommendations for physical activity of moderate intensity (64-76% HRmax or Borg Scale 12-13) for minimum of 30 minutes, 5 days per week or vigorous intensity (77-95% HR max or Borg scale 14-17) minimum 20 minutes, 3 days per week.<sup>32,33</sup>

Although the results of this study support the potential use of the EXG VR "Fitness Boxing" using the popular Nintendo Switch™ commercial video-game console as an alternative option in an effort to increase physical activities, there are several limitations, such as:

- (1) The research setting is conducted on a laboratory basis so that it may produce different results when conducted in the actual environment/condition;
- (2) The sample size is relatively small (n = 15);
- (3) The effects/responses are unknown in other population groups (women, children, elderly);
- (4) How long the participants are in the intensity of moderate or vigorous physical activity is not examined, so that further research is needed to produce specific results for adjustment of exercise prescription;
- (5) This type of exercises cannot be performed by general population of Indonesia, due to the cost and infrastructure that are very diverse (availability/supply, electricity, etc.). To be able to improve cardiovascular fitness and provide various other health benefits, physical activity (including VR EXG) with specific prescription is needed. This is not yet known and requires further research with a longer study duration, in diverse populations and different settings.

## Conclusion

This research concludes that in healthy male adults, playing the VR EXG "Fitness Boxing" Nintendo Switch™

provides cardiovascular responses (increase in heart rate and systolic blood pressure), moderate to vigorous physical activity intensity, and causing pleasant feelings. It has the potential as alternative means of increasing physical activity, avoiding boredom, increasing compliance and physical activity continuity. However, it should be emphasized that playing VR EXG using Nintendo Switch™ cannot replace more intensive and structured exercise programs or sports.

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