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original article

Acute cardiovascular responses in a virtual environment simulated by Nintendo Wii

Respostas cardiovasculares agudas em ambiente virtualmente simulado pelo Nintendo Wii

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Abstract – It has recently been verified using the Nintendo Wii in the health context. The aim of this study was to analyze the acute cardiovascular responses monitored by the behavior of heart rate, systolic blood pressure, diastolic blood pressure and double product in an environment virtually simulated by Nintendo Wii. The sample was consisted of 18 health college students with mean age 22.07 ± 1.34 years. The variables were observed with use of delta analysis (post value – prior value) after 25 basketball shoots in two experimental situations: (I) seating and (II) jumping vertically. The results suggest the physical activity in a virtual environment emulated by Nintendo Wii is able to change the acute cardiovascular responses, mainly when performed in association with vertical jumps. Thus, the results support the feasibility use of the Nintendo Wii in training programs and favor its indication more securely.

Key words: Arterial blood pressure; Basketball; Heart rate.

Resumo – *Recentemente, tem sido verificada a utilização do Nintendo Wii no contexto da saúde. O objetivo do presente estudo foi analisar as respostas cardiovasculares agudas monitoradas por meio do comportamento da frequência cardíaca, pressão arterial sistólica, pressão arterial diastólica e duplo produto, em ambiente virtualmente simulado pelo console Nintendo Wii. A amostra foi composta por 18 universitários saudáveis, com média de idade de 22,07 ± 1,34 anos. As variáveis foram observadas com uso de deltas (valor final - inicial) após 25 arremessos de basquetebol em duas situações experimentais: (I) com o voluntário sentado e, (II) com o voluntário saltando verticalmente. Os resultados sugerem que a prática de atividade física em ambiente virtual emulado pelo Nintendo Wii é capaz de alterar as respostas cardiovasculares agudas, especialmente, quando realizada em associação a saltos verticais. Assim, os resultados sustentam a viabilidade do uso do Nintendo Wii em programas de treinamento e favorecem sua indicação de forma mais segura.*

Palavras-chave: *Basquetebol; Frequência cardíaca; Pressão arterial.*

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INTRODUCTION

Virtual Reality (VR) is a computational technology that integrates several degrees of immersion, interaction and user engagement by using multisensory devices from a three-dimensional synthetic environment created in real time by the computer[1]. From this interface, the virtual environment can be manipulated by combining user's behaviors and reactions, which allows several applications in healthcare, such as surgical training, medical imaging, biosimulation, biomechanics, teaching, visualization with augmented reality, rehabilitation process and expansion of communication for people with special needs[2].

Recently, a new class of video games called exergames (EXG) has used VR to provide to the user the possibility of perceptual and performance emulation with potential for sensory and motor abilities development[3]. Many studies have used interactive virtual games from Nintendo Wii, the world's most popular EXG, to assess VR implications in rehabilitation process and neuromuscular training[4-6] as well as the impact of VR on physiological parameters, especially concerning energy expenditure[7-9].

To date there are insufficient scientific descriptions about acute cardiovascular responses during physical exertion imposed by EXG. The premise of studying this phenomenon is explained by the fact that the understanding of cardiovascular responses during physical exertion is critical for developing strategies and to obtain parameters that allow us to adjust training programs as well as to guarantee the safety of practitioners, especially when their clinical conditions involve higher risks[10]. Moreover, VR acts as a promoter of physical activity contents, allowing new possibilities for systematic exercise and movement.

Although acute cardiovascular responses have not yet been effectively described with the use of Nintendo Wii, it has been proposed that some Nintendo Wii games could facilitate the meeting of recommendations from the American College of Sports Medicine (ACSM) regarding the improvement and maintenance of cardiorespiratory fitness[11,12]. Miyachiet al.[11] evaluated metabolic equivalents (METs) of 12 adult volunteers who performed approximately 70 matches on Wii Sports and Wii Fit Plus. Results showed that 67% of activities were classified as of light-intensity (< 3 METs), 33% as of moderate-intensity (3 – 6 METs), and no activity was considered as of vigorous-intensity (> 6 METs). Douris et al.[12] compared physiological and psychological responses of 21 college students, healthy and sedentary, with a mean age of 23.2 ± 1.8 years, after they were subjected to 30 minutes of exercise like brisk walking on the treadmill *versus* 30 minutes of Nintendo Wii Fit on *Free Run* mode. Regarding physiological responses, the following variables were assessed: heart rate (HR), double product (DP), respiratory rate and perceived exertion. Although the exercise intensity level has been considered moderate in the two experimental situations, all variables showed significantly higher values in the virtual exercise performance.

In this context, the aim of this study was to analyze acute cardiovascular responses by monitoring the behavior of HR, systolic blood pressure (SBP), diastolic blood pressure (DBP) and double product (DP) in college students aged between 20 and 24 years during basketball shots on Nintendo Wii virtually simulated environment in the following experimental situations: (I) with the volunteer seated, position traditionally adopted by users of video games, and (II) with the volunteer jumping vertically. We hypothesized that exercise in VR induces alterations in all studied variables, especially when shots are performed in association with vertical jumps. From results obtained in this study, we can compare the virtual exercise intensity level with recommendations for physical activity, in order to verify what should be the necessary adjustments for health promotion using the studied virtual game.

METHODOLOGICAL PROCEDURES

Study type and sample

This is a cross-sectional and self-paired study whose convenience sample was composed of 18 healthy college students considered active according to the International Physical Activity Questionnaire (IPAQ) [13], normotensives, of both sexes (9 men and 9 women), with a mean age of 22.07 ± 1.34 years and body mass index (BMI) of 21 ± 5 kg/cm^2. All experimental procedures adopted meet the requirements of Law 196/96 of Conselho Nacional de Saúde, which establishes guidelines and rules for research involving humans (Instituto Federal de Educação, Ciência e Tecnologia do Sul de Minas Gerais (IFSULDEMINAS), Protocol 029/2011).

We adopted the following inclusion criteria: (a) negative responses to the Physical Activity Readiness Questionnaire (PAR-Q)[14]; (b) be classified as moderately active or active according to the IPAQ; (c) have not consumed alcohol, caffeine, ergogenic and tobacco in the three days preceding data collection; (d) have not practiced strenuous exercise 24 hours before collection; (e) be properly hydrated; (f) have slept 6-8 hours on the day preceding collection, and (g) have no prior experience with Nintendo Wii virtual games. Regarding to item "e", all volunteers were instructed to consume approximately 500 to 600 ml of water two to three hours before the assessment. The checking of criteria for inclusion "c", "d", "e", "f" and "g" was done through questions verbally answered by volunteers on the day of assessment.

Collection protocol

All subjects were evaluated at Laboratório para Atividade Física em Ambiente Virtual (LAFAV, IFSULDEMINAS – Muzambinho Campus, Minas Gerais, Brazil) in one day and individually.

Acute cardiovascular responses (HR, SBP, DBP and DP) were observed before and after 25 basketball shots in two sequential experimental situations spaced by 10 minutes: (I) with the volunteer seated on a backless bench during shots, and (II) with the volunteer jumping vertically for performing shots. In both tests, the shots' motor behavior was emulated in a virtual environment using the basketball game from Nintendo Wii Sports Resort software. For executions of tasks, we used the visual instruction provided by the software associated with verbal instructions provided by a single researcher on the technical execution of the "free throw" during the two experimental situations. Figure 1 illustrates the expected kinematic behavior of the trunk and upper limbs during shots. For the experimental situation II, the volunteer associated this sequence of trunk and upper limbs movements with a vertical jump within a marked area on the lab's floor, in order to avoid displacement in the anteroposterior and lateral-lateral plane greater than 15 cm. In the two experimental situations, if a volunteer shows a visually anomalous motor behavior, the entire sequence of shots is annulled and a new try is given 48 hours later.

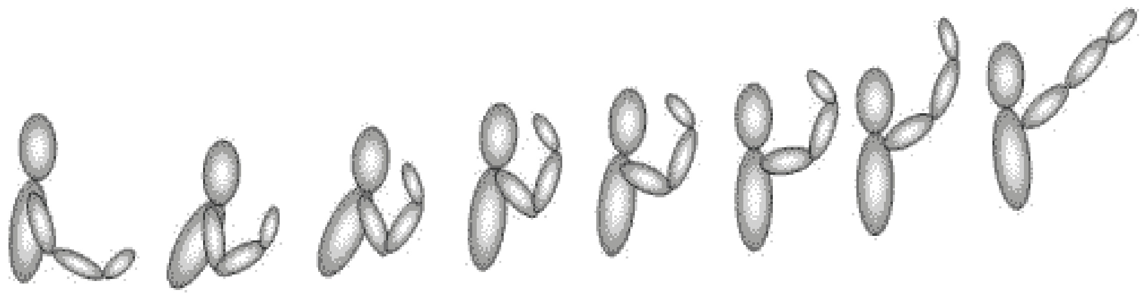

Figure 1. Expected behavior for performing shots.

For experimental routine we adopted the following procedure: initially, subjects remained seated for 10 minutes and the lowest HR of this period was considered as the initial HR for the experimental situation I. Then, initial SBP and DBP were measured. At this moment, taking advantage of the volunteer seated position, the task began. Finally, after performing 25 shots in the seated position, HR, SBP and DBP were measured again. After 10 minutes of recovery in the seated position, cardiovascular variables were similarly obtained for the beginning of the experimental situation II, in which 25 subjects performed shots in association with vertical jumps. Again, at the end of task 2, final values for HR, SBP and DBP were obtained. In both tasks, 25 shots were performed within 60 seconds, synchronized with the visual and audible feedback from the basketball game, and each shot lasted approximately 2.4 sec.

HR was monitored using a frequency counter (Polar, RS800CX model). Blood pressure measuring was performed by auscultation as recommended by the American Heart Association[15], using a mercury sphygmomanometer (Oxigel) and a stethoscope (Bic-Eternity). DP was obtained in both initial and final situations of each test from the product between HR and SBP, which correlates with myocardial oxygen consumption[16].

Virtual Environment

The virtual environment was simulated by Nintendo Wii. Input devices that allow the user-Wii interaction process are the Wii Remote and the Sensor Bar. The Wii Remote is equipped with an accelerometer capable of detecting motion in three dimensions and communicates via wireless (Bluetooth) with the Sensor Bar, which is responsible to detect and transmit to the console infrared signals generated by the Wii Remote. In the present study, we used the Wii Motion Plus accessory attached to the Wii Remote. Using this accessory, movements are reproduced more accurately, in real time (1:1) and with faithful reproduction of player's movements on the screen projection of the virtual environment[17]. The visual stimulus was produced using a multimedia projector (Epson, Power Lite S5 model), with a projected image area of 1.5 x 2.5m on a white wall. Volunteers had a physical area of 25 m^2 (5 x 5m) to perform shots and were located 1.5m from the Sensor Bar.

Statistical analysis

Initially, we used the Shapiro-Wilk test to verify the normal distribution of continuous variables. Normality was observed for all variables. Data processing included the use of the Paired Student's t test for dependent samples, which was applied to the mean delta-values (final value – initial value) for all variables related to acute cardiovascular responses (HR, SBP, DBP and DP) in the two experimental situations. We adopted a significance level of 5% ($p < 0.05$) to reject the null hypothesis. All statistical analyses were performed on SPSS version 19.0.

RESULTS

Figure 2 shows the mean delta HR (final HR – initial HR) for the two experimental situations. We observed an increase of 129% in the delta HR when subjects performed the experimental situation II (vertical jumps) compared with the experimental situation I (seated position) ($p = 0.02$). In estimating the maximum HR (HRmax) by equation 220 - age[18], we observed that volunteers showed a mean value of 51.62% of HRmax when shots were performed in the seated position, while during shots associated with vertical jumps the mean value was of 75.34% of HRmax.

Figure 3 shows the mean delta SBP (final SBP – initial SBP) for the two experimental situations. Although not significantly different ($p = 0.18$), the mean delta SBP in the experimental situation II was 37% higher than the mean delta SBP observed in the experimental situation I.

The mean deltas DBP (final DBP – initial DBP) for the two experimental situations are shown in Figure 4. While the mean delta DBP in the experimental situation I was zero, the mean delta DBP in experimental situation II was 5 mmHg. These values were statistically different ($p = 0.0052$).

Figure 5 shows the mean delta DP (final DP – initial DP) for the two experimental situations. We observed an increase of 139% in the delta DP when subjects performed the experimental situation II compared with the experimental situation I (p = 0.001).

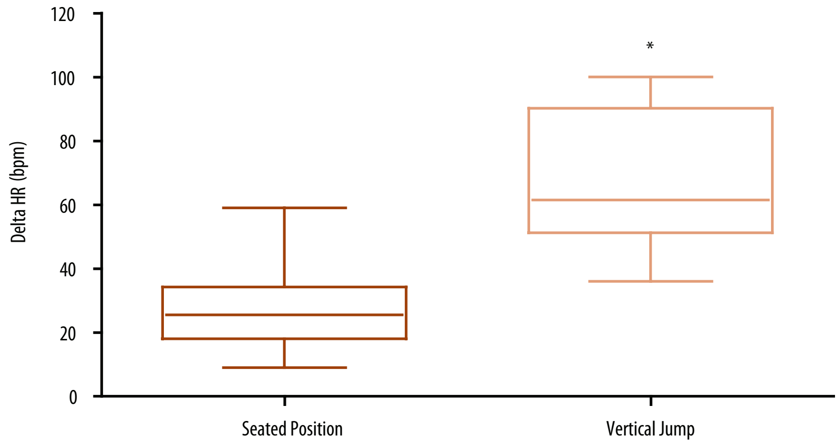

Figure 2. The mean delta HR (bpm) for the two experimental situations (seated position and vertical jumps) (n = 18). * indicates $p < 0.05$ when compared with the seated position experimental situation.

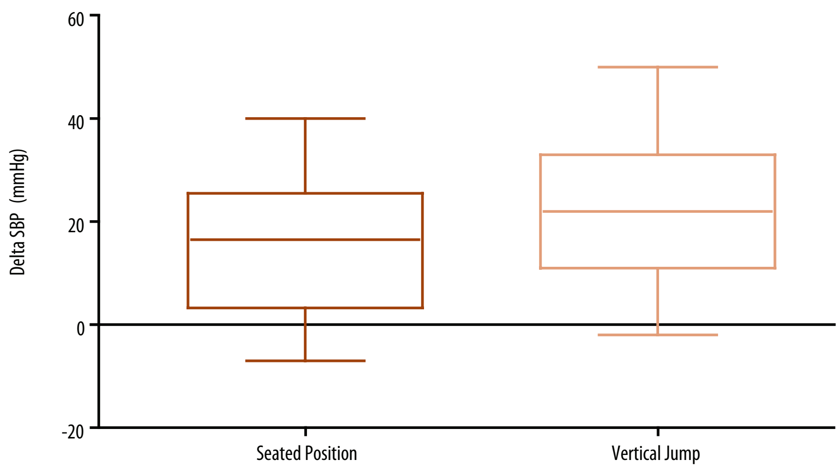

Figure 3. The mean delta SBP (mmHg) for the two experimental situations (seated position and vertical jumps) (n = 18).

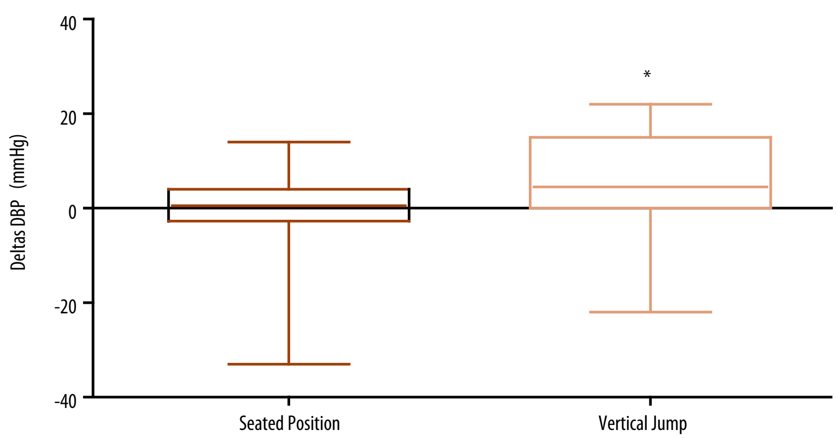

Figure 4. The mean delta DBP (mmHg) for the two experimental situations (seated position and vertical jumps) (n = 18). * indicates $p < 0.05$ when compared with the seated position experimental situation.

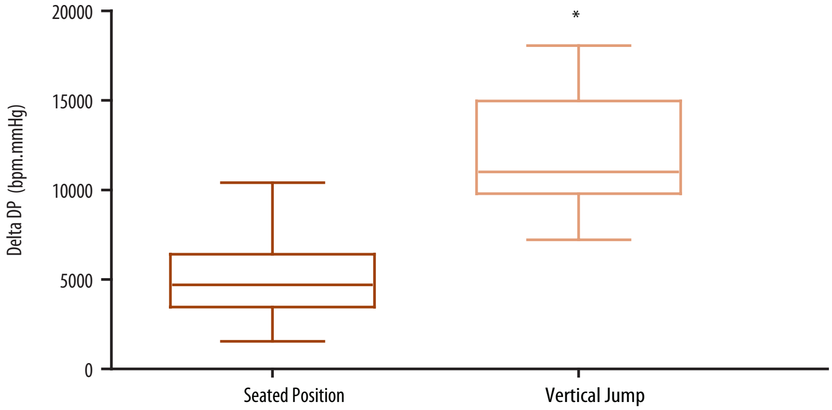

Figure 5. The mean delta DP (bpm.mmHg) for the two experimental situations (seated position and vertical jumps) (n = 18). * indicates $p < 0.05$ when compared with the seated position experimental situation.

DISCUSSION

Nowadays, many health problems are related to physical inactivity. Although the exact mechanisms responsible for the benefits of regular physical activity are still unknown, there is a vast literature that supports the recommendation of bodily movement to improve human health condition[20-22]. Thus, any tool that aims to improve the population's physical activity level, especially in social-recreational environments and in activities at home, should be investigated, so that its use is encouraged from scientific evidence. In view of this, the aim of this study was to investigate acute cardiovascular responses (HR, SBP, DBP and DP) during a sequence of 25 shots in the basketball game from Nintendo Wii Sports Resort software, which has a potential technology for favoring corporal practices: VR[3].

VR allows the creation of synthetic and fun environments for the development of several sensorimotor skills by stimulants tasks that increase the interest and motivation of users for physical activity[22]. However, the cost for building and maintaining labs or environments that use this technology is still very high, rendering moot this kind of approach for promoting health in the general population. On the other hand, feasibility and therapeutic success has been verified in the use of EXG, especially Nintendo Wii, which has tracking and performance technologies, providing a simple and of low cost VR[5,23].

Cardiovascular monitoring is critical for better understanding of physiological demands imposed by a determined physical exertion[24]. After the clarification of cardiovascular demand, we can develop strategies and obtain parameters to adjust training programs, especially for individuals with higher cardiovascular risk[10]. In the present study, we observed that during shots associated with vertical jumps HR, DBP and DP values were significantly higher when compared with those obtained when subjects performed shots in the seated position. Especially regarding to HR and DP, such behavior was expected, since shots associated with vertical jumps impose greater muscle recruitment and increased activity of the sympathetic nervous system, which, by enhancing the release of catecholamines, promotes: (a) increase in HR and stroke volume, and consequently (b) increase in cardiac output, which increases myocardial oxygen demand and extraction, increasing DP[25]. Furthermore, although SBP differences between the two experimental situations have not been considered statistically, we observed that in the experimental situation II (vertical jumps) there was a certain upward trend in values when compared to those obtained in the experimental situation I (seated position).

It is important to highlight that values of blood pressure (BP) obtained by the auscultatory method tends to underestimate the absolute values of BP during exercises, especially those of submaximal type[26]. However, considering that the probable underestimation occurred systemically, SBP and DBP results of this study should not be considered unfeasible, but taken with that caveat. Thus, when we analyze the generality of results, it appears, as initially hypothesized, that physical activity in VR induces alterations in acute cardiovascular variables, especially when greater dynamism is associated to the use of the Wii Remote, in this case, vertical jumps.

Physical activity with the purpose of health promotion should be performed according to specific recommendations concerning duration, frequency and moderate-intensity level[27]. Usually, ACSM categorizes moderate-intensity level using parameters related to oxygen consumption (VO_2), metabolic equivalents (METs), energy expenditure and HR, the last one being considered the most practical way to do it, especially when taking into account aspects like reliability, safety and cost[28,29].

In this study, we adopted the HRmax prediction from the equation HRmax = 220 - age to verify the virtual exercise intensity level[18]. Although individuals with a specific age have variables values of HRmax, the inaccuracy resulting from individual variation (± 10 bpm standard deviation for any HRmax expected for the age) has little influence in the establishment of training programs for healthy people[18]. We observed HRmax values of 51.62% (during shots in the seated position) and 75.34% (during shots associated with vertical jumps). These results indicate that these experimental conditions reached percentages of physical activity considered of light and moderate-intensity, respectively.

We considered that performed exercises were of light and moderate-intensity, thus, being observed the viability of Nintendo Wii basketball game for the improvement and maintenance of cardiorespiratory fitness, in accordance with ACSM's guidelines. In a similar study, Guderian et al.[30] evaluated cardiovascular and metabolic responses of games from Wii Fit software in adults of middle age and older to determine whether virtual games would meet ACSM guidelines for health promotion. Results showed that the exercises' mean intensity level was of 43, 4 ± 16.7% of reserve HR, with a 3.5 ± 0.96 METs and energy expenditure of 116.2 ± 40.9 kcal/session, indicating that virtual games should be considered as an alternative tool for improving physical fitness and health. This possibility has also been observed in other studies related to the interpretation of physiological demand promoted by Nintendo Wii games[11,12]. However, it is important to highlight that virtual activity alone should not replace an oriented training program. Additionally, virtual games should be seen as an auxiliary tool to help reduce the monotony, increasing entertainment and adherence to physical activity, always with the guidance of a professional.

Finally, we can mention some limiting factors of this study, such as the lack of more robust analyses on the number of participants (sample calculation), and more sensitive physiological monitoring, such as oxygen consumption and energy expenditure. However, the contribution to the state of the art and, above all, to the initial understanding of acute cardiovascular responses using Nintendo Wii for corporal practice overcomes this study's limitations, allowing us even to suggest prospects of studies investigating other games, observing chronic cardiovascular responses and assessing sedentary individuals or individuals suffering from diseases.

CONCLUSIONS

This study's results suggest that physical activity in a virtual environment simulated by the Nintendo Wii is capable of altering acute cardiovascular responses, especially when associated with vertical jumps. However, these alterations do not exceed reference values of ACSM's recommendations for physical exercise. Thus, these results support the feasibility of using Nintendo Wii in training programs and help toward its safer prescription. These results should also be considered as an initial source for the formulation of training protocols. However, further studies should be conducted to better clarify the phenomenon.

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