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Mini-trampoline enhances cardiovascular responses during a stationary running exergame in adults

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ABSTRACT: A new class of video game called exergame (EXG) has been used to promote physical activity and cardiovascular fitness, but EXGs are not as efficient as traditional aerobic exercises. However, auxiliary tools, such as the mini trampoline (MT), may enhance the physiological responses obtained by the EXG. The aim of this study was to compare the metabolic and cardiovascular responses of a stationary running EXG with and without an MT. Nineteen healthy males performed a treadmill test for the determination of VO_2max and HRmax. In sequence, the VO_2, HR, and METs were measured during the Free Run, a Nintendo Wii's stationary running EXG, according to two distinct protocols. One protocol used the traditional EXG (EXG-PT), and the other protocol used an MT during the EXG (MT-PT). The normalized data were analyzed by statistical software SPSS 20.0 using a *t*-test and ANOVA for repeated measures ($p < 0.05$). The results supported that stationary running EXG performed on an MT showed an increased intensity, in all variables analyzed, when compared with the traditional EXG. Furthermore, the MT-PT was classified as a vigorous-intensity exercise and EXG-PT as a moderate to vigorous intensity exercise. In conclusion, these findings support that the MT is a feasible auxiliary tool to enhance physiologic responses during a stationary running EXG.

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INTRODUCTION

For many years, playing video games has been associated with a sedentary lifestyle, mostly due to the physically inactive interaction mode between player and device [1]. However, a new class of video games, called active video games or simply exergames (EXG), has been modifying this stereotype [2]. Utilizing new motion detection technology, EXGs are capable of translating motor actions into personal commands to the virtual game, creating an immersive and interactive environment. The Nintendo Wii ® (Nintendo, Kyoto, Japan), one of the most popular EXG in the world, has been the object of studies that indicate effective improvements and maintenance of cardiorespiratory fitness in adults [3, 4, 5].

Despite the potential proposed by the EXG, studies that compared variables such as heart rate (HR), oxygen consumption (VO_2) positive well-being, and caloric expenditure between EXG and traditional exercises showed that the effects of EXGs might not be as efficient as those of traditional exercises; moreover, traditional aerobic exercises produce a higher intensity workout than EXGs [6, 7, 8, 9]. These findings support that EXGs can be an additional form of exercise but not a replacement for traditional exercise. However, auxiliary tools may enhance the results obtained during an EXG, improving the virtual experience and allowing users to improve upon their current results.

Thus, the mini-trampoline (MT) emerges as a possible auxiliary tool to improve the intensity of specific EXGs. The MT is a well-known apparatus used in physical activity and in a specific type of rebounding exercise, and its usage in physical fitness programs has contributed to its increasing popularity worldwide. The efficacy of MT in positively affecting quality of life, as well as cardiovascular and metabolic responses, is based on its capability to simultaneously combine balance and strength training, stabilization of the body, physical fitness, and muscle coordinated responses [10, 11, 12, 13, 14, 15].

It is well established that a physical activity program aimed at health promotion and maintenance should be provided according to specific recommendations of intensity, duration, and frequency [16]. Several physiological variables can be used to classify the intensity of an exercise. Among the most common and well-established methods are the percentage of maximal heart rate (%HRmax), percentage of maximal oxygen consumption (%VO_2max), metabolic equivalents (METs), energy expenditure, rate of perceived exertion, and blood lactate [17]. Limited studies have investigated the precise metabolic responses promoted by MT and fewer have evaluated if those responses are adequate to obtain health benefits. In addition, no other research has considered using the MT as an interventional tool aimed to surpass the results currently obtained by the EXG.

The aim of the present study was to compare the metabolic responses (VO_2, HR, and METs) of male young adults during a stationary running EXG performed on an MT and on the traditional EXG. Following previous studies in which it was proposed that performing exercises on an MT increased their difficulty level, we hypothesized that the variables evaluated would be higher with an MT than on traditional EXG.

MATERIALS AND METHODS

Subjects

The sample was composed of 19 healthy males recruited from a university student population. The subjects neither maintained a physical inactive lifestyle, exercising a minimum of 30 minutes three times per week, nor participated in an intense athletic training regimen. The guidelines for pre-activity screening of the American College of Sports Medicine (ACSM), which allow initial risk stratification for physical activity, were applied [18].

Participants were excluded if they presented any of the following exclusion criteria: a history of prior cardiovascular and metabolic diseases that preclude physical activity, recent surgical procedures, and smoking. Subjects were fully advised in regard to the risks, benefits, aims, and examination methods of the study and were clearly instructed to maintain their usual dietary and physical activity practices during the study. All participants read and signed an informed consent form, and the study was approved by the Ethics Committee designed by the Brazilian Platform (Protocol number 757.477/2016). Characteristics of the study participants are shown in Table 1.

TABLE 1. Characteristics of the study participants (n = 19).

	Mean ± SD
Age (years)	20.6 ± 2.01
Height (meters)	1.73 ± 0.08
Weight (kg)	73.6 ± 8.81
Lean Body Mass (%)	84.0 ± 5.96
Fat Body Mass (%)	16.0 ± 5.96
VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$)	55.8 ± 5.46

Note: Anthropometric and ergospirometric data on participants (n = 19, Muzambinho-MG. Brazil).

Study protocol

All the procedures were performed at the Physical Activity in Virtual Environment Laboratory (LAFAV, IFSULDEMINAS, Campus Muzambinho, Minas Gerais, Brazil). The experimental design consisted of two blocks: block 1 was composed of one session (day 1) of anthropometric assessments (height, weight, and body composition), ergospirometric parameters (VO_2max and HRmax), and to conclude the first session, each participant playing Nintendo Wii Fit Free Run for 20 minutes to ensure an equal experience with the EXG between the participants.

Block 2 was composed of two sessions (day 2 and day 3). On the second day of the study, participants were randomly divided into two groups, labeled “sample A (n = 10)” and “sample B (n = 9)”. Sample A first played Nintendo Wii Fit Free Run on a hard, wooden surface as the traditional EXG (EXG-PT), and sample B first played the same Wii-game but on an MT (MT-PT). On the third day, sample A performed the game under the MT-PT condition and sample B under the EXG-PT condition. This counterbalanced fashion was thought to minimize the “carry-over” effect of the sequence of the execution of the protocols. Thus, all participants performed both protocols, and no difference was found between the responses of sample A and sample B. The sessions were separated by 48 hours. All procedures were individually monitored by a trained and experienced researcher (Figure 1).

Block 1: *Anthropometric assessment and ergospirometric parameters*

The subjects’ body weights, heights and body composition (lean mass and body fat) were analyzed by using a Bioelectrical Impedance Analyzer (RJL systems, Quantum II, Clinton Township, MI, USA). To qualify for bioelectrical impedance analysis, the participants were required to meet the following conditions: (a) abstain from ingesting antidiuretic medications, alcoholic beverages, and food or beverages containing caffeine for the last 24 hours prior to the test; (b) avoid vigorous exercise and sauna for the last 8 hours prior to the test; (c) obtained a minimum of 8 hours’ sleep and ingested the recommended amount of water the day preceding the test [19].

The VO_2max was assessed on a treadmill by measuring respiratory gases with the VO2000 portable automated system (MGC Diagnostics, Saint Paul, MN, USA). The unit, including battery pack, harness, and cables, weighs 1.5 kg and uses the preVent™ Pneumotach to measure ventilation from expiratory flow volumes. This gas analyzer uses a proportional sampling valve and a 3-breath average for the measurement of oxygen uptake (VO_2), carbon dioxide output (VCO_2), and minute ventilation (VE) every 10 seconds. The Breeze Suite software v. 6.4.1 (MGC Diagnostics, Saint Paul, MN, USA) was used for data collection and manipulation.

Before each VO_2max determination, the gas analyzer was calibrated according to the manufacturer’s instructions. Additionally, one HR monitor (Polar, S810; Polar Electro Oy, Kempele, Finland) was used continuously to obtain HRmax. The incremental exercise test

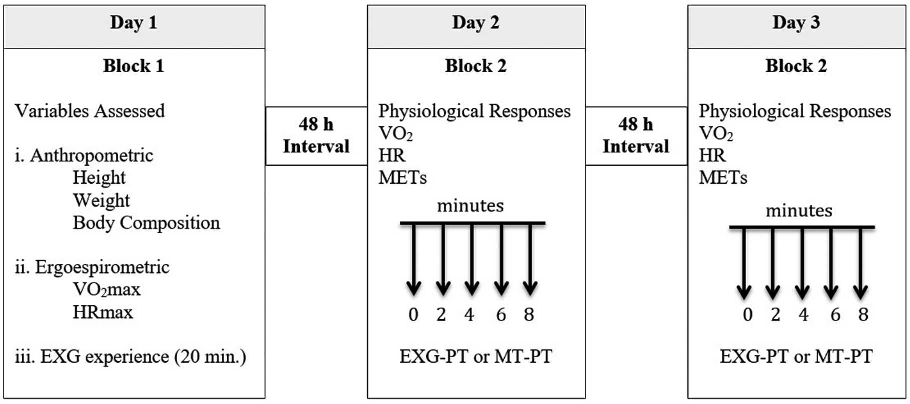

FIG. 1. Timeline of the experimental design. The experimental procedures were performed in 3 different days (sessions). Each session 48 hours apart of the others. During Block 2, physiological responses were measured during the running EXG approached by two different protocols. Randomly, one protocol was performed on a hard wooden surface as the traditional EXG (EXG-PT) or it was performed on a mini-trampoline (MT-PT). After 48 hours, the participant finished the Block 2 performing the remaining protocol. During block 2 physiological responses were taken in 5 different moments: Baseline (moment 0), minute 2, 4, 6 and 8.

followed the protocol proposed by Worley [20]. The test was initiated at 2.5 mph and a 4% grade. Every 2 minutes, the treadmill speed was increased by 1 mph, and the 4% grade remained constant. As the primary criterion, VO_2max was defined as the point at which a plateau in VO_2 occurred with an increasing workload. To determine if there was a plateau in the VO_2 during the maximum test, the highest mean value of oxygen uptake found in the last 30 seconds of each stage was used. A variation ≤150 $mL.min^{-1}$ in VO_2 after the speed was increased was considered a plateau. The following were adopted as secondary criteria: (a) HR ≥90% of predicted HRmax for age (220 – age); (b) RER ≥1.10; and (c) ≥16 points on the 20-point Borg scale [21]. When these criteria were not met, the peak VO_2 (VO_2peak) was assumed to be the average of the three highest values found during the test [22]. An automated filter was used to exclude VO_2 data that presented a respiratory quotient (RQ) <0.6 or >1.2, or a VO_2 or VCO_2 <50 mL/min [23].

Block 2: *Measurement of physiological responses during the EXG*

The Nintendo Wii console simulated the virtual environment. The input device that allowed interaction between the EXG and the subject was a Wii Remote, which is equipped with an accelerometer capable of detecting motion in three dimensions and communicates via Bluetooth with the EXG, responsible for detecting and transmitting to the console infrared signals generated by the Wii Remote. Thus, the movements were reproduced accurately in real time, allowing an authentic reproduction of the player's movements in the projection screen's virtual environment [24,25]. The software Wii Fit Plus, which contains approximately 50 different exercises, was used.

All the participants played the Wii Fit Plus game, Free Run during the EXG-PT and the MT-PT test phases. The EXG-PT was performed directly on the floor. In contrast, the MT-PT was performed on an MT. In both protocols, the Wii Remote was attached to the medial third of the participant's right thigh with an elastic band. Each protocol was performed for 8 minutes at a self-paced intensity. The subjects were instructed to run as they would in their own homes. The virtual distance (VD), a score given by the Free Run game as feedback for the player, is described to be a reliable measure of the intensity of the game [26]. They were not given a set pace, but they were instructed to cover as much VD as possible during the first protocol [26, 27]. The VD covered in the first protocol was recorded, and the participants were advised to achieve this same distance in the second protocol. The correct running technique was demonstrated to the participants, and verbal reminders were given throughout to ensure that the participants lifted their knees. This was necessary to prevent shuffling of the feet, which resulted in a faster step rate, and therefore a larger VD, without a similar increase in the physiological response [26].

During these procedures, physiological responses (VO_2, HR, and METs) were measured using the VO2000 device (MedGraphics, Saint Paul, MN, USA) coupled with an HR monitor (S810; Polar Electro Oy, Kempele, Finland). Before each experimental procedure, the system was calibrated. Gas exchange and HR were collected continuously for 10 minutes in both protocols. Using Breeze Suite software, the physiologic data were separated into different time segments (Figure 1). Data from the first 2 minutes were windowed and averaged to determine the baseline (at this moment each participant was sitting comfortably in front of the Wii console). In the remaining 8 minutes, data were windowed and averaged every 2 minutes to determine the physiological responses during the physical effort. For the purposes of this study, the variables VO_2, HR, and METs were used during the EXG.

The variables VO_2 and HR were normalized to the maximum achieved during the incremental exercise test and then presented as mean percentages (%VO_2max and %HRmax). Metabolic equivalents (which expresses the energy cost during a specific physical exercise to a reference metabolic rate, set by convention to 3.5 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$) were presented as the means of absolute values. These values were used to classify the exercise intensities, based on the ACSM stratification, according to the following intensity ranges: (a) very light (<37% of VO_2max, <57% of HRmax, or <2.4 METs); (b) light (37%–45% of VO_2max, 57%–63% of HRmax, or 2.4–4.7 METs); (c) moderate (46%–63% of VO_2max, 64%–76% of HRmax, or 4.7–7.1 METs); (d) vigorous (64%–90% of VO_2max, 77%–95% of HRmax, or 7.1–10.1 METs); and (e) near-maximal to maximal (≥90% of VO_2max, ≥96% of HRmax, or ≥ 10.2) [28].

Statistical analysis

Data were processed, and statistical analysis was performed using SPSS version 20.0 (SPSS Inc, Chicago, IL). Shapiro-Wilk test demonstrated a normal distribution of data. A paired *t*-test was used to compare differences between the overall average of EXG-PT and MT-PT over three variables (%VO_2max, %HRmax, and METs) expressed as a mean percentage (± SD). Two-way ANOVA for repeated measures was performed to compare differences between the experimental protocols over five time points (baseline and minutes 2, 4, 6, and 8). Bonferroni's post hoc test was used to indicate statistical differences between groups. Differences were considered statistically significant at $p < 0.05$.

RESULTS

Oxygen consumption

The *t*-test revealed that the overall average of %VO_2max in the MT-PT was significantly higher than that in the EXG-PT ($p < 0.001$) (Table 2). The exercise intensity in the MT-PT was considered as vigorous (68.9 ± 17.2 %VO_2max) and that in the EXG-PT as moderate (53.4 ± 8.9 %VO_2max). Two-way ANOVA for repeated measures revealed a significant time effect ($p< 0.001$) for both EXG-PT and MT-PT (Figure 2). In addition, it was indicated a significant interaction between protocols. Post hoc test indicated a significantly higher %VO_2max in MT-PT than in EXG-PT at minutes 4 ($p = 0.039$), 6 ($p < 0.001$), and 8 ($p < 0.001$) (Figure 2).

Cardiovascular responses

The *t*-test indicated that the overall average of %HRmax in the MT-PT was significantly higher than that in the EXG-PT ($p = 0.013$) (Table 2). The exercise intensity during the MT-PT was considered as moderate to vigorous (76.5 ± 15.5 %HRmax) and that in the EXG-PT as moderate (67.4 ± 12.2 %HRmax). Two-way ANOVA for repeated measures revealed a significant time effect ($p < 0.001$) for both EXG-PT and MT-PT (Figure 3). In addition, it was indicated a significant interaction between protocols. Post hoc test indicated a significantly higher %HRmax in MT-PT than in EXG-PT at minutes 6 ($p = 0.016$) and 8 ($p = 0.001$) (Figure 3).

Metabolic equivalents

The *t*-test revealed that the overall average METs in the MT-PT was significantly higher than that in the EXG-PT ($P < 0.001$) (Table 2).

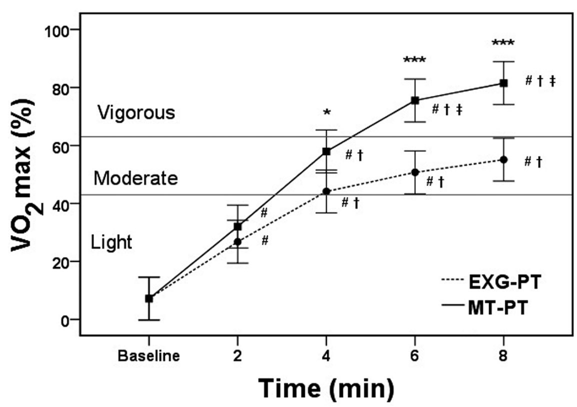

FIG. 2. Significant differences on time effect within protocols: # represents difference from baseline (p<0.05); † represents difference from minute 2 (p<0.05); ‡ represents difference from minute 4 (p<0.05). Significant differences between protocols: * (p<0.05); *** (p<0.001).

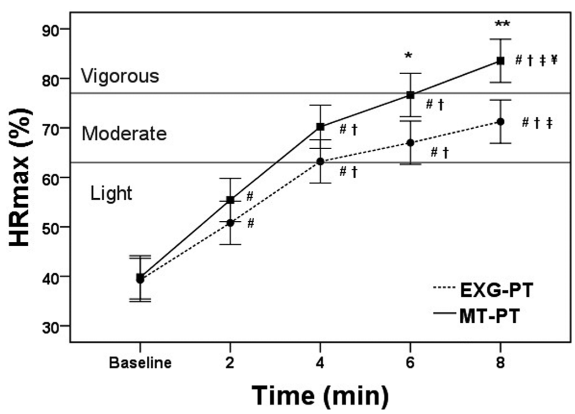

FIG. 3. Significant differences on time effect within protocols: # represents difference from baseline (p<0.05); † represents difference from minute 2 (p<0.05); ‡ represents difference from minute 4 (p<0.05); ¥ represents difference from minute 6 (p<0.05). Significant differences between protocols: * (p<0.05); ** (p<0.01).

The exercise intensity during both the MT-PT and EXG-PT were considered as vigorous (7.7 ± 2.1 METs and 6.0 ± 1.1 METs, respectively). Two-way ANOVA for repeated measures revealed a significant time effect ($P = 0.001$) for both EXG-PT and MT-PT (Figure 4). In addition, it indicated a significant interaction between protocols. Post hoc test showed that METs were significantly higher in the MT-PT than in the EXG-PT at minutes 4 ($P = 0.022$), 6 ($P = 0.019$), and 8 ($P = 0.015$) (Figure 4).

DISCUSSION

The main finding of this study is that all the analyzed variables (%VO_2max, HRmax, and MET) demonstrated a greater physiological demand during the running EXG performed on the MT than during that performed in the traditional EXG. Thus, the MT-PT promoted more intense exercise than the EXG-PT, confirming the initial hypothesis. In addition, analyses of the variable means enabled the stratification of the intensity, based on the ACSM guidelines, of each protocol, classifying the MT-PT as a vigorous-intensity exercise and the EXG-PT mainly as a moderate-intensity exercise.

Although the variables allowed a general classification of the protocols, it is important to elucidate the specific classification of each variable. According to the %VO_2max and %HRmax values, the EXG-PT is a moderate exercise, and the MT-PT is a vigorous exercise. In contrast, the METs values classified both the EXG-PT and MT-PT as vigorous exercises. This difference between the result of each variable reflects the importance of multi-variable evaluation in order to provide more solid and conclusive results. A study conducted by Soltani et al. [17], for instance, evaluated several cardiovascular and metabolic variables during a swimming-based EXG, and proposing that many factors can influence the player's response to the game. Therefore, it is important to explore the physical demands of EXG playing in more detail in order to provide specific responses to EXGs.

Another interesting finding of this study is the time effect of each protocol. Even though an interaction and a significant difference between protocols were found in all variables analyzed, MT-PT and EXG-PT demonstrated similar time effect for the METs, %HRmax (2, 4 and 6 minutes) and %VO_2max (2 and 4 minutes). In this case, the MT-PT demonstrated to be significantly more intense than the EXG-PT after minute 4 according to the variables %VO_2max and METs and after minute 6 according to the variable %HRmax. In addition, these results demonstrate that either EXG-PT or MT-PT achieved moderate to vigorous intensities during the exercise, which suggests the viability of these exercises for improvement and maintenance of cardiorespiratory fitness [16, 29, 30, 31].

Guderian et al. [32] evaluated the heart rate reserve, energy expenditure, and METs during several Wii Fit aerobic games in middle-aged and older adults. The results for the Free Run game were 64.4 ± 24.5% of the heart rate reserve, 5.7 ± 1.5 METs, and an energy expenditure of 8.5 ± 3.1 kcal/min, classifying the game as a moderate-intensity exercise. These findings corroborate with our results which indicates that the Free Run game can generate a considerable level of exercise intensity in adults. In a comprehensive study, Miyachi et al. [33] evaluated METs in 12 adults performing approximately 70 of the Wii Fit Plus games. Their findings suggest that including the Free Run 22 of the games that were analyzed could be considered as moderate-intensity exercise (3–6 METs), and none presented a vigorous intensity (>6 METs). These findings support the results obtained in our study. However, when performed on the MT, Free Run was considered a vigorous intensity exercise. Interestingly, when we evaluated the progression of METs during the exercise, the MT-PT and EXG-PT were demonstrated to be a vigorous intensity activity after minute 4 and minute 6 of exercise, respectively.

Studies have compared the Free Run EXG with traditional treadmill running. Douris et al. [27], investigated 21 sedentary adults and suggested that performing Free Run EXG for 30 minutes presented a higher intensity (HR of 142.4 ± 20.5 bpm and Double Product of 19,843.1 ± 3,406.8) than 30 minutes of treadmill walking at 3.5 miles per hour (HR of 123.2 ± 13.7 bpm and Double Product of 16,865.3 ± 3,234.0). However, the authors based their results solely on absolute values. Differently, Roopchand-Martin and Nelson [34], evaluated 28 trained adults during 10 minutes, using a repeated measure design and controlling the intensity with a metronome, and reported that the treadmill running was considered a vigorous-intensity exercise (%VO_2max 72.01±17.55, %HRmax 83.25±10.99, and METs 8.34±2.27) being significantly more intense than Free Run EXG (%VO_2max 55.49±15.68, %HRmax 78.60±11.04, and METs 6.44±2.02). Our study, which evaluated the same variables with a similar experimental design, was able to demonstrate that the MT-PT, even with lower average values of

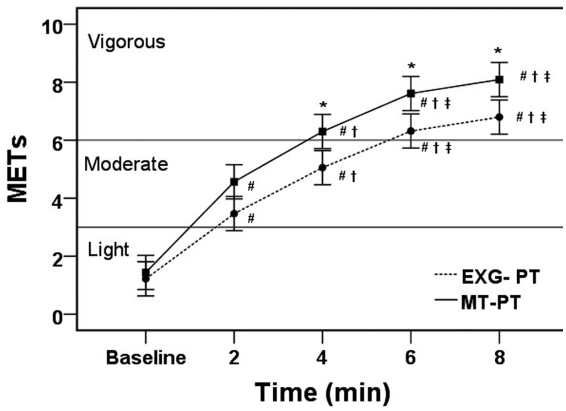

FIG. 4. Significant differences on time effect within protocols: # represents difference from baseline (p<0.05); † represents difference from minute 2 (p<0.05); ‡ represents difference from minute 4 (p<0.05). Significant difference between protocols: * (p<0.05).

TABLE 2. Descriptive Statistics of Data (n = 19; Muzambinho-MG, Brazil).

	EXG-PT	MT-PT	
	Mean ± SD	Mean ± SD	P Values
% VO_{2max}	53.4 ± 8.9	68.9 ± 17.2***	p < 0.00`
% HR_{max}	67.4 ± 12.2	76.5 ± 15.5*	p = 0.013
METs	6.0 ± 1.0	7.7 ± 2.1***	p < 0.001
VD	1515 ± 321	1498 ± 298	p = 0.850

%VO_2max (68.9 ± 17.2), %HRmax (76.5 ± 15.5), and METs (7.7 ± 2.1), was considered as a vigorous intensity exercise such as the treadmill running presented by Roopchand-Martin and Nelson [34].

Other studies have been proposed the MT as a useful tool for exercise training. For example, a study developed by Sukkeaw et al. [35] suggested that aerobic dance performed on an MT, compared with a dance performed on a hard surface, contributed to increased leg muscular strength, decreased foot plantar pressure, and more effective balance training. Even though our study did not evaluate the same variables, this study partially corroborates our findings, which propose that exercises performed on an MT could generate greater physiological responses than those performed on a rigid and stable surface. We hypothesized that the higher physiological demands promoted could be due to the rebounding and instability of the elastic surface of the MT, thus it would require a greater effort to perform the exercise and maintain balance. Furthermore, other studies have indicated that the MT has a great potential to promote physical fitness, body composition modifications, and beneficial cardiovascular and metabolic responses [36, 37, 38]. However, as far as we know, no other study has investigated the cardiovascular responses to the MT during an EXG.

It is worth mentioning that both protocols (EXG and MT) were performed at the participant's own pace, and studies suggest that these exercises positively affect training adherence, motivation, and affective responses [39, 40, 41]. However, self-paced exercise could be influenced by external factors such as mood and motivation, thus leading to differences in our study. In order to control this situation, the VD provided by the Free Run game was used as a reference measure [26]. Therefore, at the first session of block 2 (day 2), the participants were instructed to cover as much VD as they could. Subsequently, at the second session of block 2 (day 3), the participants were instructed to cover the same amount of VD as they had in the first session. No difference was found between the VD performed in the two protocols (Table 2).

Because sports EXG are designed to replicate the real sports and their physiological demands, new techniques that could contribute to a more meaningful experience of EXG should be considered and evaluated. In practical terms, this study provides evidence that the MT used during the Free Run EXG can promote a more effective and intense workout than the EXG by itself and that it can be considered a vigorous- intensity exercise fulfilling the ACSM requirements for physical activity.

Despite the findings of this study, some limitations should be acknowledged. For example, this study was performed over a single time and short-term intervention, measuring only acute cardiovascular responses in the experimental protocol. Future studies should evaluate the long-term effect of the MT during EXGs and measure metabolic variables in order to provide a better understanding of its physical demands. In addition, the sample was selected from a young and healthy population, thus the results should not be extrapolated to other populations. Additionally, future studies should consider using a more reliable method to control the external load instead of the Free Run VD. Thus, as promising as the running EXG can be it has limitations that should be analyzed and possibly overcome.

CONCLUSIONS

In conclusion, the stationary running EXG performed on an MT showed an increased intensity, with respect to all variables analyzed, when compared with the traditional EXG. Considering the %VO_2max, %HRmax, and METs, the exercises performed during the MT-PT and EXG-PT were classified vigorous and moderate activities, respectively. These findings support the use of an MT as an auxiliary tool to improve the results of Free Run EXG practice.

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Conflict of interest declaration

The authors declare no conflict of interest.

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