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Original Article

Exergame vs. Aerobic Exercise and Functional Fitness of Older Adults: A Randomized Controlled Trial

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Abstract:

Purpose: To compare the effects of physical exercise with exergame and aerobic exercise on the functional fitness of healthy older adults. Methods: This randomized, controlled trial included 27 participants aged 55 and over randomized into two intervention groups: exergaming (n = 13) and aerobic exercise (n = 14). The exergame program was conducted using games that simulate sports activities using an Xbox 360 Kinect™. In the aerobic program we used ergometers. Both groups completed 36 sessions, each lasting 60 minutes, for 3 days per week for 12 weeks. We used the Senior Fitness test to verify functional fitness. Results: The mean age of the participants was 59.8 ± 4.1 years and 60.7 ± 3.6 for the exergaming and the aerobic groups, respectively. We found a relationship interaction between the intervention time and the groups for the “arm curl” test ($p <$ .05). Both groups exhibited improvement in the "30-s chair stand" test and the Timed Up and Go test ($p <$. 05) after the intervention. The exergaming group demonstrated significant post-intervention results for the “arm curl” test and the 2-minute step test. Conclusion: The exercise program with exergame contributed to improving the parameters of functional fitness of healthy older adults. The effects were comparable to those of an aerobic exercise program of moderate intensity.

Key words: aging, training, video games, virtual reality exposure therapy.

Introduction

Aging causes changes in the physiological systems that may impact on reducing the functional performance in older adults. This reduction often compromises the ability to perform daily tasks (Buchman, Wilson, Leurgans, Bennett, & Barnes, 2015). In turn, physical exercise can delay the deleterious effects of aging by preserving the independence and autonomy of older adults (Nakano, Otonari, Takara, Carmo, & Tanaka, 2014). The benefits of aerobic exercise on functional fitness are well described in review and meta-analysis studies (Chudyk & Petrella, 2011; Santos-Parker, LaRocca, & Seals, 2014). An alternative exercise that has been discussed in recent years is exergaming (Molina, Ricci, Moraes, & Perracini, 2014; Primack et al., 2012), a virtual experience that mix physical exercise and video games.

Studies with older adults showed that interventions with different games of exergame can improve cognitive and physical functions (Maillot, Perrot & Hartley, 2012) and the quality of life (Maillot, Perrot, Hartley, & Do, 2014) of their practitioners. However, few studies have evaluated the effects of exergaming-based exercise program on the functional fitness of older people (Maillot et al., 2012; Maillot et al., 2014). Some studies have used balance sets and force plates to assess the balance (Padala et al., 2012), strength and endurance of the lower limbs (Jorgensen, Laessoe, Hendriksen, Nielsen, & Aagaard, 2013; Kim, Son, Ko, & Yoon, 2013). However, other physical parameters such as aerobic endurance need to be better investigated. Furthermore, although some interventions with sports exergame (which simulate sport practices) have been explored (Maillot et al., 2012; Maillot et al., 2014), it is also necessary to assess the effects of these games compared to conventional exercises. Game modalities like "cybercycle" (Anderson-Hanley et al., 2012), and balance games (yoga, slalom skiing) (Padala et al., 2012) were compared to conventional activities (i.e., stationary bikes and walking), with similar results on cognitive functions and balance when evaluated. However, no studies comparing the effects of sporting exergame with conventional exercise for the functional fitness of older adults. Given the above, the objective of this study was to compare the effects of physical exercise with sporting exergame and aerobic exercise on ergometers on the functional fitness of healthy older adults.

Material & Methods

Trial Design

The trial was designed as a randomized parallel two-arm clinical investigation, in which outcomes were assessed at baseline and after 12 weeks of intervention.

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The research protocol was approved by the Research in Ethics Committee of the Universidade Federal de Santa Catarina (No 329 649; 09882613.0.0000.0121 CAAE), and all the participants signed a written informed consent for their participation. The trial is registered with number RBR-9crpzc (http://www.ensaiosclinicos.gov.br/rg/RBR-9crpzc/).

Participants

The study participants were older adults (55 and over) of both sexes. To participate, the respondents had to meet the following eligibility criteria: no participation in a regular physical exercise program in the previous three months; submission of a medical certificate allowing them to practice physical exercise; no previous contact with exergame; no visual and/or hearing impairment to limit the identification of images, colors and sounds. The following exclusion criteria were also adopted: a diagnosis of Alzheimer's disease; Parkinson's disease; disabling neurological diseases; psychiatric comorbidities; neurodegenerative diseases; severe cardiovascular disease; using beta-blockers and/or antidepressant drugs.

Setting and Participant Recruitment

Information on the project was disseminated through the main webpages of the Universidade Federal de Santa Catarina (UFSC), in order to recruit respondents to participate in the project. It was also advertised through posters and leaflets distributed in the institution, health centers, churches and condominiums, near the university.

People who contacted the team responsible for the survey were pre-selected following the eligibility criteria. Those who met these criteria were invited to attend personally to UFSC (Sports Center) for further information about the research. Eligible participants who agreed to participate were evaluated at baseline. A properly trained staff (students of the graduation course in Physical Education) was responsible for the assessment, supervision and guidance of the exercise programs.

Interventions

Exergaming group. The training sessions were conducted with the Microsoft Xbox 360 Kinect™ console. All activities were carried out in a laboratory, with a temperature kept constant (~ 21 - 24 degrees Celsius). To develop the program, a room was equipped with a 240 cm x 180 cm projection screen (Tecnomast), an Epson Powerlite 96W projector, and a Satellite As878 speaker set. In the space of the gaming area, a tatami/EVA mat was placed to prevent possible slippages.

During the sessions, we used the following games that simulate sports from the Kinect Sports Ultimate Collection: athletics, bowling, boxing, skiing, soccer, tennis, and table tennis. The sports games were alternated, following a pre-established plan, two sports games being used per session. We also used the following short games ("mini-games"), which took on average 1-2 minutes: racing; goal shooting; super defense; body ball; and rallies. These "mini games" are games in which one must make as many points as possible. They were used during the warmup period for each session. All games give visual and auditory information, according to the participant's performance. The choice of the games was made based on the preferences of the participants in the pilot study.

The activities were performed in pairs for a period of 12 weeks with a weekly frequency of three days (alternating). Before the program began, there were three sessions/week to familiarize the participants with the activities.

A total of 36 sessions was conducted. The exercise sessions of 60 minutes comprised: 5 to 10 minutes of static and dynamic stretching, in addition to a "mini game"; 40-45 minutes of sporting games and; 5-10 minutes of breathing exercises and stretching. The intensity of the activity was monitored by using a heart rate monitor (Polar® S810i model).

Aerobic exercise group (active control). The aerobic exercise training program was conducted at the Laboratory, whose temperature was kept constant (~ 21-24 degrees Celsius). Cycle ergometers (Moviment®, Biocycle 2600 Electromagnetic model) and electric treadmills (Moviment®, model LX 160 and LT 140) were used). Prior to the start of the intervention, the participants underwent three sessions of aerobic exercises to familiarize them with the activities with the ergometers.

The activities were performed in groups, during a 12-week period, with a total of 36 sessions. The activities had a weekly frequency of three alternate days and each lasted 60 minutes. The training intensity ranged from 40% to 59% of the Heart Rate Reserve (HRR), characterized as aerobic physical activity of moderate intensity (Garber et al., 2011). To monitor the intensity of the sessions, the participants used a heart rate monitor (Polar®, FS1 model).

The increase of the training's volume and intensity was carried out progressively. The training sessions were divided into warmup (about 10 minutes) aerobic exercise, main activity (approximately 40 minutes) and breathing exercises and stretching (10 minutes). The time of the main activity was divided between the cycle ergometer and the treadmill (~ 20 minutes for each device).

Outcomes

The tests were administered individually to each participant at the laboratory, where the temperature was maintained in the range 21-24 degrees Celsius. Senior Fitness Test (Fullerton test) was applied to assess muscle strength and endurance of the lower limbs; upper muscle limb strength; agility and dynamic balance; aerobic endurance. The following tests were performed (Rikli & Jones, 1999):

1) The ‘30-s chair stand’ test (SR) checked the muscle strength and endurance of the lower limbs. The score was obtained by the total number of correct performances in a 30-second interval. If the participant was in the middle of the elevation at the end of 30 seconds, it would be considered a performance.

2) The "arm curl" test verified the upper muscle limb strength. The score was obtained by the total number of correct performances in an interval of 30 seconds (2 kg for women and 4 kg for men). The dominant side of the body was considered in order to do the test.

3) The timed up and go test (TUG) verified agility and dynamic balance. The test consists of rising from a chair, walking as fast as possible (without running) for 2.44 meters, turn around a cone and return to the chair, sitting down again. The participants performed two trials and the shortest time was computed.

4)The “2-minutes step” test (2MST) verified aerobic endurance. An adjustment was made for the appropriate height of each participant’s knee lifting; - we considered the midpoint between the patella and the anterior superior iliac spine. The score was obtained by the total number of successfully achieved liftings in the set time.

Sample Size

The sample size calculation was performed after data collection. The sample losses were considered. For the calculation, we adopted the significance level of 5% (type I error) and a test power of 80% (type II error) for statistical analysis by mixed design ANOVA. First, we calculated the effect size (*f*) for the partial variance analysis of all participants, considering the performance in the TUG test (in seconds). It was determined that for a moderate effect size (Cohen, 1992) of 0.5, the verification of minimal clinically significant difference, 11 participants would be required in each group.

Randomization

The participants were randomized into two groups: exergaming and aerobic exercise. For randomization, by means of random number values, we used the Microsoft Excel for Windows software package.

Statistical Methods

Descriptive statistics were performed for the quantitative and qualitative variables (mean, standard deviation and distribution in percentages). Differences between the groups were compared by the chi-square test and Fisher’s exact test (qualitative variables) and Student’s t test for independent samples (quantitative variables) after normality verification by the Shapiro-Wilk test.

The comparison of the means for the variables of muscle strength, agility/dynamic balance and aerobic endurance, inter and intra-group, pre- and post- intervention were performed by ANOVA using the mixed model (group x time), incorporating the dependence between observations. The analysis of the training’s effect size was conducted by Effect-size, according to the proposal suggested by Cohen (1992): < 0.2 = small effect, 0.2 to 0.8 = medium and > 0.8 = large. For detailing the interaction we used the post hoc SIDAK test.

In all analyzes, the statistical significance level was set at 5% ($p \leq .05$). Data analysis was performed using the Statistical Package for Social Sciences (SPSS version 16.0). The tabulation of the data was carried out ‘blind’ by an investigator not involved in the collection and intervention. Data analysis was also performed ‘blind’ to control unintended bias on the part of investigators/statistics.

Results

Sixty-five eligible participants were identified (Figure 1), and 29 of them were not randomized for they did not meet the inclusion criteria, reported lack of interest or time for participation in the project. Thirty-six participants (14 men and 22 women) were randomly divided in the exergaming or the aerobic exercise group. The participants (n = 9) which, during the intervention period, participated in some other exercise program; used medication containing beta-blockers, or drugs for the treatment of depression, anxiety and cardiovascular disease; and had a frequency of less than 75% of the total sessions, were excluded from the analysis, as described in Figure 1. Twenty-seven performed the post-intervention assessments, 13 in the exergaming group and 14 in the aerobic group.

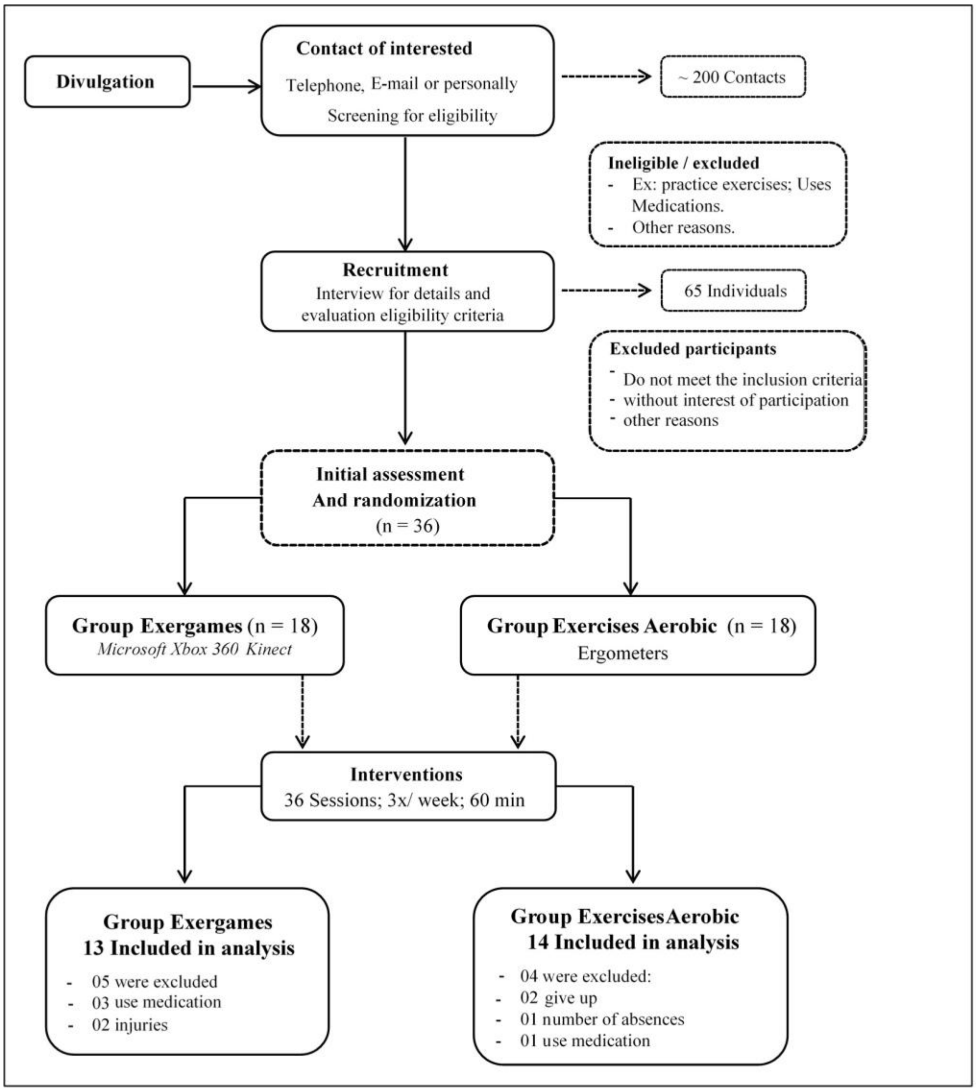

Fig. 1. Diagram of the phases of the study.

The adherence to the intervention programs identified by the class attendance, was 90.6% and 86.9% for the exergaming and aerobic groups, respectively. There was no difference between the groups ($p < .05$).

Table I shows the characterization of the participants, according to the intervention group. Their age ranged from 54 to 68 years old, with a mean age of 59.8 ± 4.1 years and 60.7 ± 3.6 for the exergaming and the aerobic groups, respectively. There were no significant differences in age between the groups ($p = .528$). The participants of both groups had a high education level. There were no statistical differences between the groups for the variables sex, living arrangements and perception of health status at baseline.

Table 1. Characterization of the participants

	Groups				*p*-value
	Exergaming (n=13)		Aerobic(n = 14)		
	n	%	n	%	
Sex					.24
Male	3	23.1	8	57.1	
Female	10	76.9	6	42.9	
Schooling					.583
Elementary school	0	0.0	1	7.1	
High school	0	0.0	1	7.1	
Technical school	2	15.4	0	0.0	
Under graduation	8	61.5	9	64.3	
Graduation	3	23.1	3	21.4	
Living arrangement					.29
Lives alone	5	38.5	3	21.4	
Lives accompanied	8	61.5	11	78.6	
Self-rated health				.320	
Very good	6	46.2	4	28.6	
Good	6	46.2	10	71.4	
Medium	1	7.7	0	0.0	

Table 2 shows the statistical F values of the mixed ANOVA, significance and effect size for evaluation of the performance capability regarding the differences between the groups, time and interaction. There was a significant interaction effect for the "arm curl" test and a significant trend ($p \leq .20$) was observed for the 2MST test. Significant values for the intervention period (time) were found for the '30-s chair stand', the TUG and the 2MST tests.

The analysis of the training's size effect (Table 2) showed little effect on the results when comparing the groups, except for the "arm curl" test. In general, the results of the means of the tests for the interventions were similar.

Table 2. Values of the F test and effect size (d) for the functional fitness tests

	30-s chair stand		Arm Curl		TUG		2-min. step test	
Parameters	*F*	*d*	*F*	*d*	*F*	*d*	*F*	*d*
Group	0.334	0.013	0.448	0.018	2.158	0.079	2.670	0.097
Time	24.184*	0.492	3.596	0.126	28.495*	0.533	11.915**	0.323
Group x Time	0.120	0.005	7.990***	0.242	0.505	0.020	2.579	0.094

Note. Group = Exergaming x Aerobic; Time = Initial x 12 weeks; Group x time = interaction time; TUG= "timed up and go test". * significant at the p <. 001 level. **Significant at the $p < .005$ level. *** Significant at the $p < .05$ level.

The means and standard deviations of the functional fitness tests and comparisons between groups and pre/post-intervention period are presented in Table 3. Although the F test values did not show significance for group and time interaction in the 2MST, $p = .121$ indicated a trend of interaction between group and time.

Table 3. Mean values and standard deviation of the functional fitness tests for the exergaming (n= 13) and aerobic groups (n = 14) pre- and post-intervention

Parameters	Pre-intervention	Post-intervention
30-s chair stand (n° repetitions)		
Exergaming	14.38 ± 3.28^{Aa}	18.23 ± 3.29^{Ab}
Aerobic	13.50 ± 2.17^{Aa}	17.93 ± 4.58^{Ab}
Arm Curl (n° repetitions)		
Exergaming	17.15 ± 3.93^{Aa}	19.69 ± 4.17^{Ab}
Aerobic	17.92 ± 2.13 ^{Aa}	17.43 ± 2.17^{Aa}
TUG (seconds)		
Exergame	5.31 ± 0.87^{Aa}	4.80 ± 0.38^{Ab}
Aerobic	5.71 ± 0.64^{Aa}	5.04 ± 0.54^{Ab}
2-minutes step test (n° repetitions)		
Exergame	92.92 ± 19.94^{Aa}	110.53 ± 16.14^{Ab}
Aerobic	87.28 ±2 0.26^{Aa}	93.71 ± 22.81^{Ba}

Note. Data expressed as the mean and standard deviation (M ± SD); TUG = "timed up and go test". Equal majuscule letters represents no statistic difference (5%) between the groups. Equal minuscule letters represents no statistic difference (5%) between the times.

Discussion

The results of this study showed that the effects of exercise with an exergame program (sports games) were comparable to the effects of aerobic exercise in improving the functional fitness of the participants. After 12 weeks of intervention there was a marked improvement in muscle strength and endurance of the lower limbs (30-s chair stand), agility and dynamic balance (TUG) for both groups. For the exergame group we also observed significant results in aerobic endurance (2MST), strength and endurance of the upper limbs (arm curl).

The positive effect of exergame in improving muscle strength of the lower limbs of older adults had been previously documented (Chen et al., 2012; Jorgensen et al., 2013; Kim et al., 2013; Maillot et al., 2012). These results were independent of the type of game used in the investigations and assessment tools. That is, whereas in the present study we used games that simulated sport activities, other studies used interactive rehabilitation games (Chen et al., 2012) and balance games (Kim et al., 2013). In this study, the percentage increase in the number of repetitions of the 30-s chair stand test (26%) for the exergame group was higher than the 21% recorded by Maillot et al.(2012) using intervention with sports games.

For the exergame group, the improvement in performing the 30-s chair stand test may be due to adjustments related to the neuromuscular function and a consequent greater efficiency in recruiting motor units (Aagaard, Suetta, Caserotti, Magnusson, & Kjaer, 2010). The practice of games requires sensory and motor interaction, including information processing and activation of the lower neuromuscular system (Pichierri, Murer, & Bruin, 2012). In addition, the requirement of the isometric contraction of the muscles of the lower limbs in games like skiing, may have contributed to the results.

Regarding aerobic exercise, the improved muscle strength and endurance of the lower limbs is consistent with studies in the literature (Crane, Macneil, & Tarnopolsky, 2013; Ferrara, Goldberg, Ortmeyer, & Ryan, 2006; Harber et al., 2009). These results suggest that activities like walking/running (Ferrara et al., 2006) and on cycle ergometers (Harber et al., 2009) contribute to increased levels of strength, contraction speed and muscle power. Aerobic training has the capacity to alter the contractile characteristics of the muscles at the cellular level by stimulating protein synthesis in older adults, thus favoring, increased muscle strength (Harber et al., 2009).

In this study, the participants of the exergame group showed a positive variation of 15% in muscle strength and endurance of the upper limbs, evaluated through the arm curl test. This result is similar to that verified by Maillot et al. (2014) with the same test after a 12 weeks' intervention by means of sporting exergame. Games such as boxing, tennis, table tennis and bowling, included in the intervention program, require a major involvement of the upper limbs, contributing to the increase of the arm curl test's outcome. In this study, the differences in the strength of the upper limbs (arm curl test) between the groups may be related to the principle of specificity of the exercises. The activities performed on the ergometers primarily involved the lower limbs, while sporting exergame allowed for a greater participation of all body segments.

The results showed that both intervention groups improved their performance in the TUG test, which checks the agility and dynamic balance. These results are consistent with other studies of different interventions with exergame (Duque et al., 2013; Maillot et al., 2012; Padala et al., 2012; Pichierri et al., 2012; Schoene et al., 2013; Van Diest, Lamoth, Stegenga, Verkerke, & Postema, 2013) and independent of how the balance was evaluated. In some studies (Padala et al., 2012; Van Diest et al., 2013) the interventions were carried out by means of balance games, using a Wii balance board. Padala et al. (2012) compared the results of the exergame (balance games) to an active control group, as in this study, and showed that the results for the TUG test were similar to the results of the group that performed aerobic walking exercise.

Static and dynamic exercises can improve the ability to withstand challenges from postural sway or other destabilizing stimuli caused by the environment or even self-motion. (Docherty, Valovich McLeod, & Shultz, 2006). Exercises targeting the balance are generally recommended for people with reduced mobility and risk of falls, although there is no specific recommendation for the frequency, intensity or type of exercise (Chodzko-Zajko et al., 2009). In this study, the improvement in agility and balance can be explained by the characteristics of the interventions. The sports games require the participants' quick changes of direction, visual attention and motor control to perform precise movements and improve muscle strength of the lower limbs. Furthermore, previous studies reported that exergame contribute to the development of the executive function and spatial perception (Maillot et al., 2012; Pichierri et al., 2012), thus contributing to the improvement of the cognitive function related to the equilibrium (Schoene, Valenzuela, Lord, & de Bruin, 2014). These factors contribute to the improved performance in the agility and balance activities.

As for aerobic endurance (2MST), the results showed a significant upward trend for the exergame group. Although the aerobic group showed an improvement in the 2MST performance, the differences were not significant. Positive effects on aerobic endurance after interventions with sports exergame have been previously documented (Maillot et al., 2012; Maillot et al., 2014). Maillot et al. (2012) found increased endurance (14%) after intervention with sports exergame assessed by the 6-minute walk test. In the study of Maillot et al. (2014), healthy elderly who performed sport and balance games improved their aerobic endurance after 12 weeks of completion of the exercise program with sports games.

The sporting exergame used in this study are characterized as interval type games, i.e. games having different intensities and resting periods. A possible explanation for the improvement in aerobic endurance can be attributed to adjustments related to changes in the oxidative capacity of muscle fiber and the metabolic adaptations related to the exercise (Burgomaster et al., 2008). Such adaptations reverberate in more efficient responses to the cardiorespiratory system and the cellular level, promoting improved aerobic endurance (Burgomaster et al., 2008). However, further studies are needed in order to explore and better understand the adaptive mechanisms of this type of exercise.

Although the results for the aerobic exercise program have shown a modest positive change for aerobic endurance, the effects were not significant. Studies with larger samples are needed to better understand the interaction existence between the groups.

The study has limitations and strengths. The first limitation is related to the use of indirect measures to assess functional ability. Assessments with direct instruments such as a cardiopulmonary exercise test, maximal contractions tests and the use of force platform are recommended, as they have greater accuracy for the measurements. However, the used battery is reliable (Rikli & Jones, 1999) and has been used by other researchers investigating the activities with exergame (Maillot et al., 2012; Maillot et al., 2014), in addition to being a tool easy to use and commonly used in clinical practice. Possible battery reproducibility problems were minimized by prior training and standardization of the assessors. Another limitation refers to the difficulty in controlling the progression of training intensity for the exergame group, even if the used sports games allowed varying the levels for implementation of the activities. Nonetheless, one must consider that other factors influence the intensity of this type of activity, as the level of competitiveness of the participants and the motivation for their practice which would result in higher energy costs (Anderson-Hanley, Snyder, Nimon, & Arciero, 2011). Among the strengths, the use of an active control group, which is a conventional exercise used in interventions with older adults, stands out. An intervention with active control, aerobic exercise, allowed to show that intervention with exergame is at least as good as conventional exercise besides being a playful physical activity and allowing social interaction (Meneghini, Barbosa, Mello, Bonetti, & Guimarães, 2016). Another strong point refers to the use of sporting exergame not yet explored as an intervention in studies with older adults. And finally, our control regarding the inclusion and exclusion criteria of the participants which enabled more homogeneous groups.

This study supports that the sports exergame provided benefits related to improved functional fitness in older adults. However, the effects of different types of games in the improvement of the physical attributes and the feasibility of using these devices in home-based exercise programs need to be further studied.

Conclusion

In conclusion, the results obtained in this study showed that both exercise programs, aerobic and exergaming, were able to provide improvement in parameters of functional fitness of older healthy adults. The effects relating to muscle strength of the lower limbs, mobility and balance suggest similarity between the interventions. For aerobic endurance, strength and endurance of the upper limbs there were significant differences for the exergame group.These results provide concepts for future studies that evaluate the direct relationship between exergame and functional fitness, mainly in relation to cardiovascular adaptations.

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