Acute and Chronic Effects of Exercise in Health

Effect of exergames and conventional proprioceptive exercise on muscle strength and functional performance of elderly women

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Abstract - Objective: To assess and compare the effect of a training protocol with exergames and conventional proprioceptive exercise on muscle strength and functional performance of elderly women. **Methods:** This was a randomized controlled clinical trial. The final sample of the present study consisted of 45 women with aged ≥ 60 years and allocated into three groups: conventional proprioceptive training (n = 15), exergame (n = 15), and control (n = 15). Over 8 weeks, participants underwent 24 intervention sessions, three times a week. The conventional training group performed exercises involving walking and postural balance, organized in a circuit with seven stations. The exergame group performed exercises using the Xbox Kinect One® videogame, simulating five sports activities: jet ski racing, climbing, soccer, bowling, and tennis. The variables assessed were functional mobility through the Time Up and Go Test (TUGT), Five Times Sit to Stand Test (FTSST), and muscle strength through the Handgrip Strength Test (HGS). **Results:** A temporal analysis showed a significant large effect reduction in the time taken to perform the FTSST in both exercise protocols, with conventional training reducing by 1.47 s and exergame by 1.22 s. In the walking test performance, assessed by TUGT, an interaction with a large effect was observed between the control and conventional training groups, with worsened performance in the control group and improved performance in the conventional training group. **Conclusion:** No differences were found between the conventional training and exergame groups, indicating that both interventions can be used as strategies to improve functional performance in elderly women.

Keywords: elderly, muscle strength, exergame, proprioceptive conventional training.

Introduction

The aging process is accompanied by changes that make the body more vulnerable to injuries from internal and external sources[1]. Failures in neuromuscular transmission, greater infiltration of fat in the muscles[2], and structural changes in muscle fibers determine changes such as a slow and progressive decrease in the amount of muscle mass and strength from the fifth decade of life onwards, becoming more significant from the seventh decade onwards[3].

Thus, the structures and functions of all the tissue elements of the different systems of the elderly person's body undergo changes, reducing their ability to increase mobility and resist losses[4], which causes elderly women to reduce their functional capacity, increasing the risk of falls, institutionalization, comorbidity and even premature death[5-7].

A systematic review and meta-analysis study published by García-Hermoso et al.[8] found that people with lower levels of muscle strength had a higher risk of all-cause mortality. While a study by Zhao et al.[9] found that people over the age of 60 who have greater handgrip strength cope better with the challenges of aging. In a more recent study, the reduction in muscle strength was greater in older people aged over 80, those who were insufficiently active, and those with a high level of sedentary behavior[10].

However, knowing that regular physical activity reduces the signaling of inflammatory damage and contributes directly to good functional performance and healthy aging, lifestyle changes are of fundamental importance, especially adhering to/increasing the practice of these activities[11].

There are already recommendations for exercise practices for adults over 65, which include balance and strength exercises involving all muscle groups, to improve functional capacity and prevent falls[13,14].

Conventional proprioceptive exercise programs increase postural control, balance, and locomotion. These exercises, among others, of at least moderate intensity, promote health benefits for the elderly and can control or prolong physical functions[15,16].

Although different types of physical activity and exercise have shown beneficial effects, specific prescriptions can improve functional outcomes in older people[11]. Thus, alternative modalities such as exergames may be able to generate beneficial transformations in the physical function of the elderly[12,17], as well as motivate them and promote greater adherence to their practice, since they require physical effort from the practitioner to interact with the game[18].

With the technological advancement of exergames, their use can be incorporated into clinical practice, optimizing strategies that encourage the practice of physical exercise that improves the autonomy of the elderly. It is possible to maintain the functional mobility and balance of elderly people in an interactive and efficient way through the practice of exergames. In prevention and rehabilitation programs, it can positively impact the physical, social and psychological domains and help improve adherence in elderly people, overcoming existing barriers related to physical exercise[17].

Thus, since a high level of sedentary behavior is a very significant risk factor for the health of the elderly[19], physical exercise is considered to be an excellent tool for eliminating factors that contribute to physical limitations with advancing age. This reinforces the importance of looking for strategies that focus on maintaining muscle mass and strength to pass through the aging process autonomously and satisfactorily[20].

However, there is little evidence on the effects of exergames on maintaining/increasing muscle strength and functional performance in elderly people. Most studies compare exergames only with control groups, i.e. without the presence of another programmed activity. Therefore, it is important to determine whether the exergame promotes better benefits for strength and functional performance when compared to conventional proprioceptive training. Therefore, this study aims to evaluate and compare the effect of a training protocol with exergames and conventional proprioceptive exercise on the muscle strength and functional performance of elderly women.

Material and methods

Study design, location, and participants

This study was carried out under the recommendations of the Consolidated Standards of Reporting Trials (CONSORT)[21]. It is a single-blind, randomized controlled clinical trial. The information used for this study was taken from the database of a larger study called “Effects of proprioceptive training on the sensory and functional responses of elderly women”, carried out in the city of Jequié in 2019.

This research was carried out with the participants randomly assigned to the intervention and control groups, allowing the characteristics (age, weight, height) to be distributed similarly between the groups[22]. The population consisted of 155 participants from four community groups for the elderly, located in the municipality of Jequié, BA.

The sample size was defined based on the results of a pilot study with 15 elderly women (5 in each group), and the outcome was the difference (i.e. performance before training or control - performance after training or control) in the Time Up and Go Test (TUGT). For the sample calculation, we considered $\alpha = 0.05$ and the power of the test $(1 - \beta) = 0.95$, with 3 groups (control, conventional proprioceptive exercise and exergame), which resulted in a sample of 36 individuals (i.e. 12 in each group). Considering the possibility of sample loss over the course of the 8-week intervention, the sample size was estimated with a margin of loss of 25% in each group, so a sample number of 15 elderly women per group was expected (i.e. a total sample of 45 elderly women). The sample size was calculated using G*Power® software version 3.

The following inclusion criteria were adopted: a) a minimum age of 60 years and a maximum of 79 years; b) elderly women who had not practiced any form of physical exercise (guided and regular) in the last three months; c) absence of cognitive impairment assessed using the Mini-Mental State Examination (MMSE) instrument, the version used in Brazil and adapted by Bertolucci et al[23]. d) absence of a diagnosis of diabetes mellitus; e) absence of vestibular disorders; f) absence of cardiovascular diseases limiting the practice of exercise; g) absence of any visual or hearing impairment that would compromise the proposed training; h) absence of skin lesions on the feet and amputations; i) absence of osteoarticular lesions that could prevent or hinder training; j) independent walking and locomotion without auxiliary devices; k) absence of claudication or any other alteration to the gait pattern for any reason; l) availability to attend training sessions throughout the study.

Data collection

Before the interventions began, a pilot study was carried out with 15 elderly women, which enabled adjustments to be made to the participants’ training time, better handling of the resources used, and standardization of some assessment methods. The participants in this pilot study were not part of the main study sample.

After screening according to the established criteria, out of a total of 155 participants in the social groups, 50 elderly women remained, who were randomized by age group (60-69/70-79 years) and BMI (low/high), thus seeking greater homogeneity in the allocation between the groups. The median was used to categorize BMI. Based on the stratification, the participants were distributed into four groups: age group (60-69 years) and low BMI, age group (60-69 years) and high BMI, age group (70-79 years) and low BMI, and age group (70-79 years) and high BMI.

The participants were then randomized into blocks of three individuals for each stratum[24]. The blocks were randomized using Microsoft Excel software version 2013, and the codes were then distributed in the three study groups (control group, conventional training, and exergame). The entire process was carried out by a researcher with no clinical involvement in the trial, thus guaranteeing the confidentiality of the allocation.

The control and conventional groups were made up of 17 participants and the exergame group of 16 participants, with each group ending up with 15 participants at the end of the study. Losses were related to elderly women dropping out (Figure 1)[25].

Training protocols

Training was carried out 3 times a week for 8 weeks, in a total of 24 sessions, lasting 50 min per session, with a minimum interval of 48 h between each session. The training protocol was organized as follows: warm-up (10 min), training (30 min), and cool-down (10 min), with blood pressure and heart rate monitored before and after the activities. The warm-up was a walk (4 min) and stretching exercises for the muscles of the upper and lower limbs and trunk (6 min). The warm-up was followed by breathing exercises (5 min) and stretching (5 min).

To minimize external influences, participants were instructed to maintain their daily activities unchanged during the intervention. The training sessions were suspended if the participants experienced dizziness, malaise, muscle pain, increased blood pressure, or any other physical discomfort. At the end of the study, for ethical reasons, the control group, which did not participate in any form of exercise during the intervention period, received conventional proprioceptive training under the same conditions established in the protocol.

Conventional proprioceptive training protocol

The conventional proprioceptive training protocol involved gait and postural balance training and was organized spatially in the form of a circuit with different textures and obstacles, made up of seven stations. The materials used were 1 mattress measuring 120 × 70 × 10 cm (station 1), 1 foam module - mini crossbar measuring 190 × 22 × 10 cm (station 2), 4 agility rings measuring 42 cm in diameter (station 3), lateral proprioceptive board measuring 60 × 36 × 8 cm (station 4), 2 agility cones measuring 23 × 14 cm (station 5), 1 proprioceptive disk measuring 40 cm in diameter (station 6), and 3 agility barriers measuring 70 × 15/ 70 × 20/ 70 × 25 cm (station 7).

In groups of three, the elderly women performed exercises at each station involving walking forwards, backward, and sideways; exercises in bipedal and unipedal support with eyes open and closed; agility training with ball throwing and multidirectional movements. Each participant remained at each station for two minutes, with a thirty-second break between stations. After going through the seven stations, they went backward, forwards, and sideways through all the stations continuously without breaks, with only a thirty-second break at the end of each circuit, until they had completed the proposed time of 30 min. The exercises in the conventional proprioceptive training protocol were based on the literature consulted[26,28].

Training protocol with exergames

Training with exergames was carried out using the Xbox Kinect One video game from Microsoft®. This console uses motion sensor technology, the Kinect, which captures players' movements, i.e. they are sensitive to changes in direction, speed, and acceleration, thus allowing games to be controlled with body movement, without the need to use any manual control[29]. The game used was Kinect Sports Rivals, and the elderly women exercised with the following sports: jet ski racing, climbing, soccer, bowling, and tennis.

The games ranged from basic motor skills: squatting and standing, jumping, turning, tilting the trunk, moving lateral and antero/posterior, and moving the arms in all directions; to more complex motor skills that stimulated coordination, balance, and stability.

The training with exergames was carried out in a room with no objects to interfere with the performance of the elderly women, in which the games were projected onto the wall using an Epson PowerLite S8+ projector and a set of Multilaser 60 WRms Sp088 speakers.

The participants were accompanied by researchers and performed the activities in pairs, barefoot, and positioned in front of the Kinect sensor at a distance of three meters. Each session consisted of training with three games previously selected by lottery, with each game lasting 10 min, for a total of 30 min.

The order of the games in each session was also drawn by lot; every six sessions a new draw was made, where one game was replaced by another, allowing the participants to have contact at the end of the training with all five selected games. The training was standardized so that all the elderly women played the same games and each game lasted the same amount of time.

Response variables and data collection instruments

The study used a questionnaire comprising sociodemographic and health-related information, as well as

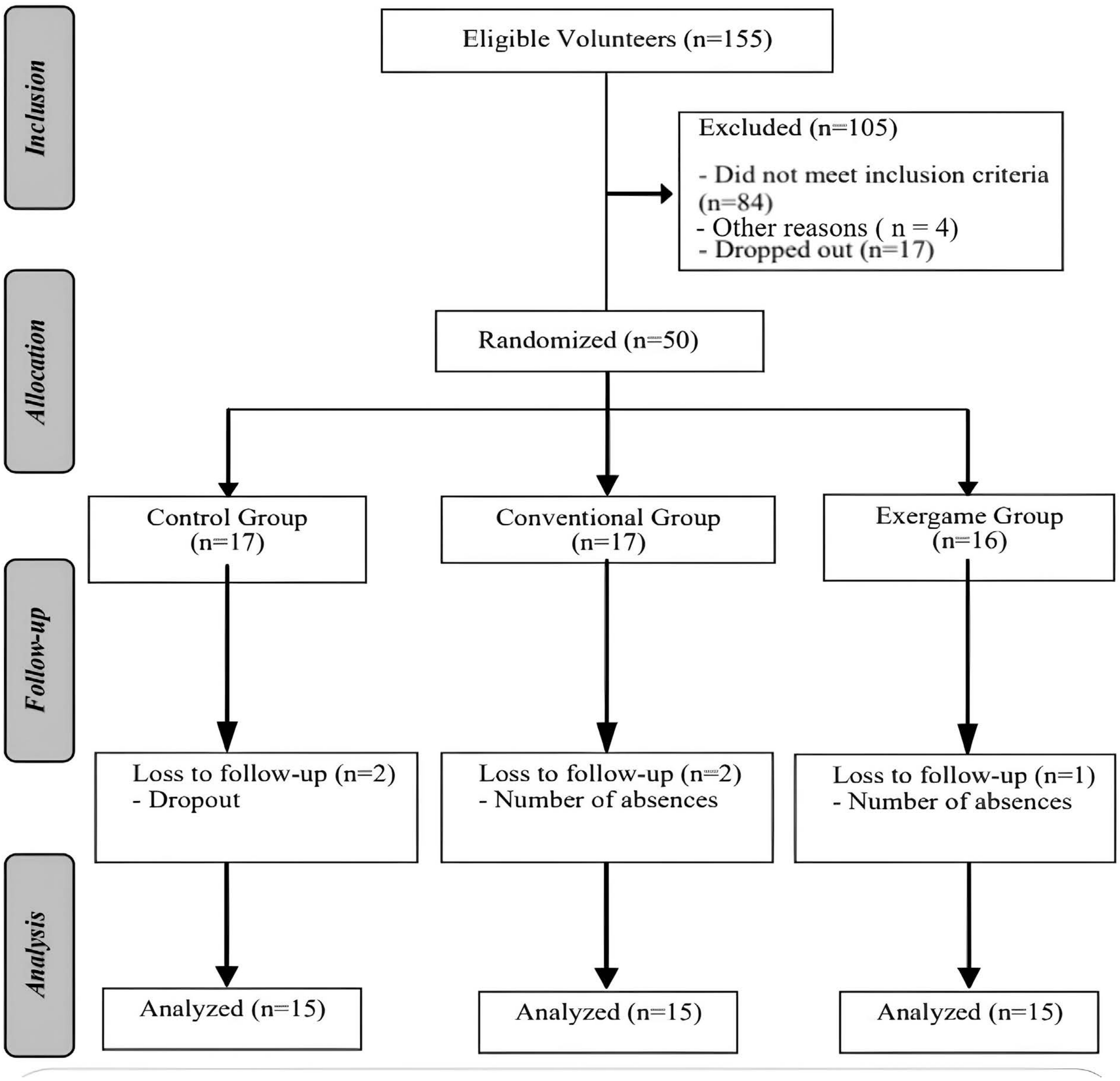

Figure 1 - Flow diagram of the elderly women taking part in the study (adapted from Mascarenhas[25]).

muscle strength and functional performance tests and anthropometric measurements.

The characterization variables were: age, height, and body mass. Age (complete years) was obtained by self-report, while body mass was measured using a portable digital scale (Zhongshan Camry Electronic, G-Tech Glass 6, China), in kilograms (kg). Height was measured using a stadiometer fixed to the wall, in meters (m), according to Lohman's recommendations[30].

Muscle strength

Upper limb muscle strength was assessed using handgrip strength using a force transducer (EMG System Brasil, São José dos Campos, SP) with a sampling rate of 2 kHz, as described by Pereira et al.[31]. The volunteers were instructed to sit with their arms relaxed at their sides and to position their dominant arm at 90° elbow flexion with the forearm in a neutral position. The handle of the device was adjusted according to the size of the palm, with the fingers in 90° flexion at the proximal and distal interphalangeal joints and the thumb in 90° abduction.

Two maximal isometric contractions of handgrip strength were performed, with a rest interval between attempts of 1 min. The participants were carefully instructed to perform a contraction “as quickly and as forcefully as possible” while holding the contraction for 3 s.

The extensometer signal was smoothed by a zero-lag fourth-order digital Butterworth filter with a cut-off frequency of 15 Hz and the best handgrip strength performance between trials was used for analysis.

Functional performance

Two tests were used to assess functional performance: 1) Time Up Go Test (TUGT), used to measure habitual walking speed over a distance of 3 m with the elderly women being instructed to walk the route at their usual pace. The test was carried out twice and the shortest execution time was used for analysis[32], adapted by Nakano[33]. 2) Five Times Sit to Stand Test (FTSST), used to assess lower limb strength and performance. To carry out this test, the elderly women were instructed to stand up and sit down from the chair, at a height of 44 cm, as quickly as possible with their arms crossed over their chest and the time was recorded in seconds[32], adapted by Nakano[33]. The test was considered valid when completed in a time ≤ 60 s. Before the tests began, the participants were shown the best way to perform each task.

Statistical analysis

The Intention to Treat (ITT) principle was used in the analysis. Descriptive analysis was carried out by calculating means and standard deviations for quantitative variables and absolute and relative frequencies for categorical variables. The mean values of the characterization variables were compared between the groups using the One-way ANOVA test. The means of the muscle strength and functional performance variables were compared using the mixed-effects ANOVA model, both for effects between groups (control, conventional, and exergame), intra-group over time (pre versus post), and interaction effect (group versus time).

Post-hoc analysis was carried out using the Sidak test. Sphericity was analyzed using Mauchly's W test and Greenhouse-Geiser correction was applied if necessary. The quadratic partial eta (ηp2) was also used to check the effect size, with the following classification: $\eta p^2 \geq 0.0099$-0.0057 = small effect; $\eta p^2 > 0.0588$ - 0.1378 = medium effect; $\eta p^2 \geq 0.1379$ = large effect[34]. A significance level of 5% ($p < 0.05$) was used for all analyses. The analyses were carried out using SPSS version 21.0 statistical software.

Ethical aspects

This study was carried out in accordance with resolution no. 466/2012 of the National Health Council, and was approved by the Research Ethics Committee of the State University of Southwest Bahia (UESB), under opinion no. 2.627.047. The study was registered in the database of the Brazilian Registry of Clinical Trials (REBEC), registration number RBR-592yyp. The participants signed the Free and Informed Consent Term and no remuneration or reward was offered for taking part in the study. Informed consent was obtained from all individual participants included in the study.

Results

Of the 50 elderly women who started taking part in the study, only 5 did not complete it. Adherence to the intervention programs was 88.2% for the control and conventional groups, and 94.1% for the exergame group.

Table 1 shows the variables characterizing the control, conventional and exergame groups. It can be seen that there were no significant differences between the groups at baseline concerning the variables age, BMI, body mass, and height (p ≥ 0.05), demonstrating homogeneity in the allocation of participants between the groups.

Table 2 shows the comparative analysis of the HGS and the time taken to perform the functional performance tests using different exercise protocols. After eight weeks of training, there was a significant reduction with a large effect in the time taken to perform the Five Times Sit to Stand Test (FTSST) in both exercise protocols, conventional proprioceptive with a reduction of 1.47 s (p = 0.025) and exergame with a reduction of 1.22 s (p = 0.008). Concerning performance in the walking test, assessed by the TUGT, there was an interaction with a large effect for the control and conventional groups, with a worsening in performance for the control group and an improvement in performance for the conventional proprioceptive group.

Discussion

The aim of this study was to evaluate and compare the effect of a training protocol using exergames and conventional proprioceptive exercises on the muscle strength and functional performance of elderly women. The main findings were that after 8 weeks of intervention, there was a significant reduction in the time taken to perform the Five Times Sit to Stand Test (FTSST) in the elderly women who underwent conventional and exergame training, but no differences were found between the training

Table 1 - Descriptive characteristics of the control, conventional, and exergame groups.

Variables	Control $\overline{X}$ (SD)	Conventional $\overline{X}$ (SD)	Exergame $\overline{X}$ (SD)	p-value
Age (years)	68.50 (6.09)	67.25 (5.82)	72.60 (4.88)	0.451
Body mass (kg)	65.06 (11.40)	58.83 (7.28)	62.15 (13.75)	0.832
Height (m)	1.53 (0.06)	1.52 (0.04)	1,52 (0.05)	0.993
BMI (kg/m^2)	27.79 (5.09)	25.30 (1,96)	26.80 (6.33)	0.813

$\overline{X}$ = Mean; SD = Standard deviation; BMI = Body mass index.

Table 2 - Comparative analysis of HGS and functional performance of elderly women using different exercise protocols.

Variables	Control $\overline{X}$ (SD)	Conventional $\overline{X}$ (SD)	Exergame $\overline{X}$ (SD)	η_p^2	ANOVA	F	p-value
HGS (kgf)							
PRE	178.57 (46.26)	175.72 (31.98)	171.83 (20.79)	0.20	Group	1.265	0.324
POST	164.01 (32.32)	167.55 (31.21)	181.39 (27.11)	0.17	Time	1.010	0.361
				0.12	Interaction	0.706	0.517
FTSST (s)							
PRE	10.34 (1.73)	10.34 (2.07)	10.35 (1.91)	0.14	Group	1.122	0.353
POST	9.90 (1.81)	8.87 (1.94)	9.13 (1.42)	0.81	Time	30.676	0.001
				0.15	Interaction	1.255	0.300
TUGT(s)							
PRE	10.19 (3.16)	11.48 (2.75)	11.77 (2.70)	0.02	Group	0.290	0.750
POST	11.36 (2.48)	10.10 (3.03)	11.02 (1.84)	0.11	Time	1.789	0.202
				0.35	Interaction	7.438	0.003

$\overline{X}$ = Mean; SD = Standard deviation; HGS = Handgrip strength; FTSST = Five Times Sit to Stand test; TUGT = Time Up and Go Test; ANOVA; η_p^2 = partial eta-squared.

groups. An interaction with a large effect was also observed between the control group and the conventional proprioceptive group, with a worsening in performance in the TUGT for the control group and an improvement in performance for the conventional group, while the exergame group showed no significant difference.

The evidence from the current study is in line with some findings in the literature. Concerning handgrip strength, no significant intra- or inter-group differences were found after eight weeks of training using a conventional proprioceptive training protocol and exergames compared to control. The study that evaluated the effect of ten weeks of intervention with exergames in older adults[35] and a meta-analysis that evaluated 22 randomized clinical trials[36], point out that the effects produced by training with exergames on muscle strength do not differ significantly from other groups (training or control) in the HGS tests.

With regard to the FTSST, which allows lower limb muscle strength and functional performance to be assessed, the findings of this study state that elderly women had a shorter time to perform the test after carrying out the proposed training (exergames and conventional proprioceptive training). As in our study, Yu et al.[35] found differences in the strength assessed in the upper and lower limbs, in which after 4 weeks of training with exergames, the elderly showed an improvement in the muscle strength of the lower limbs assessed using the FTSST.

The different approaches to carrying out protocols with exergames have a strong influence on the findings of the studies, which may be related to the type of console used[38], the different frequencies (2x or 3x/week), and durations of the intervention (30 to 60 min)[37] and consoles with different characteristics (Wii Fit, Dance Revolution, Kinect Sports), in addition to the fact that most of them do not compare them with other types of exercise[35,38].

Direct assessments of the functional performance of elderly people are very important in terms of indicating the degree or risk of acquiring diseases and limitations associated with advancing age and the way people live. The TUGT is a test widely used to measure performance related to balance, gait, and functional capacity in the elderly[39].

This study showed that the elderly women who underwent conventional proprioceptive training completed the test faster than the control group, indicating an improvement in functional performance during walking. It should also be noted that the effect obtained on the TUGT in the group that underwent conventional proprioceptive training was more significant than in the control group. This can be explained by the types and characteristics of the sensory and musculoskeletal stimuli offered by proprioceptive training, through circuits and different speeds of execution.

Therefore, after 8 weeks with 24 training sessions, the elderly women who performed the exergame and conventional proprioceptive training protocols showed significantly better results in the variables that assess gait and balance, while the control group, which did not perform any type of training, showed a worsening in functional performance.

A systematic review study with meta-analysis, published by Suleiman-Martos et al.[36], showed that training with exergames was more efficient for the gait speed parameter when compared to conventional exercises[36]. Studies have also shown that elderly people showed improvements in postural balance and mobility assessed by the TUG when they trained with exergames[38,40,41,43]. These findings indicate that interventions using exergame protocols have been shown to be effective in improving the functional performance of elderly people[40], which may reflect better conditions for carrying out activities of daily living. The literature presents findings that contrast with our results, stating that exergame training surpasses the benefits obtained from conventional proprioceptive training[17,42] in the gait speed parameter. However, these findings compared the effectiveness of the exergame to the control group, and not to another type of training, which may justify the results found.

The differences in results may be related to the variability in the training programs and due to the number and types of groups compared. In the current study, three groups were compared (control, conventional proprioceptive, exergame), while in the aforementioned studies, only two groups were compared (control and exergame). This may also be related to the type of exergame chosen (Wii Fit, Kinect Sports, Dance Revolution, etc.), and the duration of training with the selected protocol, as some studies used 8 weeks and others up to 14 weeks.

The practice of physical exercise is accompanied by benefits, especially for older people[11], and its effects are positively effective in preventing the risk of falls and maintaining gait independence. It is therefore essential that the elderly maintain good muscle strength and functional independence for successful aging[9,44].

Thus, exergames can improve functional performance in elderly people when used alone or as part of an exercise program[43], which will contribute directly to the quality of life of these individuals, since intervention protocols with technology have been shown to be effective in improving the physical and cognitive abilities of this population[41,42].

Exergame training can be effective and motivating during prevention and/or rehabilitation programs for elderly people and with application in public health, due to the good acceptance and participation of elderly people in the proposed exercises/games[45]. Its positive impacts optimize strategies capable of preventing and rehabilitating elderly people in different clinical situations[46], being another viable tool that encourages the practice of physical exercise.

The limitation of this study is the difficulty in controlling the intensity of the exergame training, perhaps due to the competitiveness between the participants motivated during the intervention. However, more research is needed to evaluate the effects of exergames on muscle strength and functional performance in older people and to establish the ideal criteria (time of each session, frequency, and duration of the program) for its practice.

The exergame training proposal should be evaluated as a major advance in the health field, although conventional proprioceptive exercise intervention has also shown beneficial effects. However, in today's world, it is inevitable to participate in technological advances and take advantage of them in the various areas of health. Therefore, interventions with exergames not only prolong functional abilities, but also improve functional performance, which can be affected by changes in aging, and can be used as another training option for the elderly population.

Conclusion

Conventional proprioceptive training and the exergame provided improvements in the functional performance of elderly women after 8 weeks of intervention when assessed by the sit and stand test. No significant differences were found between the training groups, showing that both interventions can be used as a strategy to improve the functional performance of elderly women.

References

1. Partridge L, Deelen J, Slagboom PE. Facing up to the global challenges of ageing. Nature. 2018;561:45-56.
2. Tieland M, Trouwborst I, Clark BC. Skeletal muscle performance and ageing. J Cachexia, Sarcopenia and Muscle. 2018;9:3-19.
3. Gonçalves TJM, Gonçalves SEAB, Pereira AZ. Diretriz BRASPEN de terapia nutricional no envelhecimento. Braspen. 2019;34(3):1-68.
4. Frontera WR. Physiologic changes of the musculoskeletal system with aging: a brief review. Physical Medicine and Rehabilitation Clinics of North America. 2017;28:4.
5. Briggs AM, Cross MJ, Hoy DG, Sànchez-Riera L, Blyth FM, Woolf AD, et al. Musculoskeletal health conditions represent a global threat to healthy aging: a report for the 2015 World Health Organisation world report on ageing and health. Gerontologist. 2016;2:243-55. doi.
6. Briggs AM, Woolf AD, Dreinhöfer K, Homb N, Hoy DG, Kopansky-Giles D, et al. Reducing the global burden of musculoskeletal conditions. Bull World Health Organ. 2018;96:366-8. doi
7. Melo LA, Lima KC. Factors associated with the most frequent multimorbidities in Brazilian older adults. Ciência & Saúde Coletiva, 2020;25:3879-88.
8. García-Hermoso ACIVR, Cavero-Redondo I, Ramírez-Vélez R, Ruiz JR, Ortega FB, Lee DC, et al. Muscular strength as a predictor of all-cause mortality in an apparently healthy population: a systematic review and meta-analysis of data from approximately 2 million men and women. Arch Phys Med Rehabil. 2018;99:10.
9. Zhao X, Chen S, Liu N, Hu F, Yu J. Handgrip strength is positively associated with successful aging in older adults: a national cross-sectional study in China. J Affective Disorders. 2023;333:30-7. doi
10. Dos Santos L, Silva RR, Santana OS, Valença Neto PF, Almeida CB, Casotti CA. Fatores associados à dinapenia em idosos do nordeste brasileiro. J Phys Education. 2022;33:1.
11. El Assar M, Álvarez-Bustos A, Sosa P, Angulo J, Rodríguez-Mañas L. Effect of physical activity/exercise on oxidative stress and inflammation in muscle and vascular aging. Int J Mol Sci. 2022;23(15):8713.
12. Taylor LM, Kerse N, Frakking T, Maddison R. Video games for improving physical performance measures in older peo-

ple: a meta-analysis. J Geriatr Phys Ther. 2018;41(2):108-23. doi
13. BRASIL. Guia de atividade física para a população brasileira. Brasília: Ministério da Saúde, 2021. Available from: https://bvsms.saude.gov.br/bvs/publicacoes/guia_atividade_fisica_populacao_brasileira.pdf [Accessed 18th Aug 2024].
14. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Sports Med. 2020;54(24):1451-62. doi
15. Aman JE, Elangovan N, Yeh IL, Konczak J. The effectiveness of proprioceptive training for improving motor function: a systematicreview.FrontHumNeurosci.2015;8:1-18.doi
16. Costa JNA, Ribeiro ALA, Ribeiro DBG, Neri SGR, Barbosa DF, Avelar BP, et al. Balance exercise circuit for fall prevention in older adults: a randomized controlled crossover trial. J Frailty, Sarcopenia and Falls. 2022;7(2):60-71. doi
17. Pacheco TBF, De Medeiros CSP, De Oliveira VHB, Vieira ER, de Cavalcanti, FAC. Effectiveness of exergames for improving mobility and balance in older adults: a systematic review and meta-analysis. Systematic Reviews. 2020:9 (1):1-14. doi
18. Oh Y, Yang S. Defining exergames & exergaming. Meaningful Play 2010 Conference proceedings. East Lansing, Meaningful Play; 2010.
19. Lozado YA, Barbosa RS, Caires SS, Bomfim BSM, Dos Santos L. Implicações do elevado comportamento sedentário à saúde de idosos: uma revisão de literatura. Práticas e Cuidado. Rev de Saúde Coletiva. 2020;1:e9994.
20. Arvandi M, Strasser B, Meisinger C,Volakis K, Gothe RM, Siebert U, et al. Gender differences in the association between grip strength and mortality in older adults: results from the KORA-age study. BMC Geriatrics. 2016;16(1):1-8. doi
21. Schulz KF, Altman DG, Moher D, Consort Group. CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. J Clinic Epidemiol. 2010;340:1144-6. doi
22. Portela MC, Pronovost PJ, Woodcock T, Carter P, Dixon-Woods M. How to study improvement interventions: a brief overview of possible study types. BMJ Quality & Safety. 2015;24(5):346-54. doi
23. Bertolucci PHF, Brucki S, Campacci SR, Juliano Y. O mini-exame do estado mental em uma população geral: impacto da escolaridade. Arq Neuropsiquiatr. 1994;52(1):1-7.
24. Ferreira, JC, Patino CM. Randomização: mais do que o lançamento de uma moeda. J Bras Pneumo. 2016;42(5):310.
25. Mascarenhas CHM, Silva IES, Carneiro JAO, De Paula RP, De Paula LSR, Araújo, CM, et al. Effects of conventional proprioceptive training and virtual reality on functionality and fear of falling in elderly women: randomized clinical trial. J Clin Med Surgery. 2023;3(1):1074.
26. Santos AA, Bertato FF, Montebelo MIL. Efeito do treinamento proprioceptivo em mulheres diabéticas. Rev Bras Fisioterapia. 2008;12(3):183-7.
27. Alfieri FM. Distribuição da pressão plantar em idosos após intervenção proprioceptiva. Rev Bras Cineantropometria Desempenho Humano. 2008;10(2):137-42. doi
28. Rezende AAB, Silva IlL, Beresford H. Avaliação dos efeitos de um programa sensório-motor no padrão da marcha de idosas. Fisioterapia em Movimento. 2012;25(2):317-24.
29. Khoshelham K, Elberink SO. Accuracy and resolution of kinect depth data for indoor mapping applications. Sensors. 2012;12:1437-54. doi
30. Lohman TG. Advances in body composition assessment: current issues in exercises science. Illinois: Human Kinetic Publisher; 1992.
31. Pereira R, Cardoso BS, Itaborahy AS, Machado M. Analysis of handgrip strength from elderly women: a comparative study among age groups. Acta Med Port. 2011;24(4):521-6. doi
32. Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontology. 1994;49(2):85-94. doi
33. Nakano MM. Versão brasileira da Short Physical Performance Battery - SPPB. Adaptação cultural e estudo da confiabilidade. Dissertação [Mestrado em Gerontologia], Universidade Estadual de Campinas, Campinas; 2023.
34. Cohen J. Statistical power analysis for the behavioral sciences. Hillsdale, Lawrence Earlbaum Associates; 1988.
35. Yu TC, Chiang CH, Wu PT, Wu WL, Chu, IH. Effects of exergames on physical fitness in middle-aged and older adults in Taiwan. International Journal of Environmental Research and Public Health. 2020;17(7):2565. doi
36. Suleiman-Martos N, García-Lara R, Albendín-García L, Romero-Béjar JL, Cañadas-De La Fuente GA, Monsalve-Reyes C, et al. Effects of active video games on physical function in independent community-dwelling older adults: a systematic review and meta-analysis. J Advanced Nursing. 2022;78,5:1228-44. doi
37. Viana RB, De Oliveira VN, Dankel SJ, Loenneke JP, Abe T, Da Silva WF, et al. The effects of exergames on muscle strength: a systematic review and meta-analysis. Scandinavian J Med & Sci Sports. 2021;31(8):1592-611. doi
38. Liu, H, Xing Y, Wu Y. Effect of wii fit exercise with balance and lower limb muscle strength in older adults: a meta-analysis. Front in Med. 2022;9:812570. doi
39. Podsiadlo D, Richardson S. The timed “Up & Go”: a test of functional mobility elderly persons. J Am Geriatr Soc. 1991;39(2):142-8. doi
40. Liu M, Zhou K, Chen Y. Is virtual reality training more effective than traditional physical training on balance and functional mobility in healthy older adults? A systematic review and meta-analysis. Front Hum Neurosc. 2022;6:843481. doi
41. Benitez-Lugo ML, Suárez-Serrano C, Galvao-Carmona A, Vazquez-Marrufo M, Chamorro-Moriana G. Effectiveness of feedback-based technology on physical and cognitive abilities in the elderly. Front Aging Neurosc. 2022;14:1050518.
42. Xu W, Liang HN, Baghaei N, Xu W, Liang HN, Baghaei N, et al. Health benefits of digital videogames for the aging population: a systematic review. Games for Health Journal, 2020. Games for Health J. 2020;9(6):389-404. doi

43. Taylor LM, Kerse N, Frakking T, Maddison R. Video games for improving physical performance measures in older people: a meta-analysis. J Geriatr Phys Ther. 2018;41(2):108-23. doi
44. Wang DXM, Yao J, Zirek Y, Reijnierse EM, Maier AB. Muscle mass, strength, and physical performance predicting activities of daily living: a meta-analysis. J Cachexia, Sarcopenia and Muscle. 2020;11(1):3-25. doi
45. Rica RL, Shimojo GL, Gomes MC, Alonso AC, Pitta RM, Santa-Rosa FA, et al. Effects of a Kinect-based physical training program on body composition, functional fitness and depression in institutionalized older adults. Geriatr Gerontol Int. 2020;20(3):195-200.
46. Lima AMN, Moreira MT, Ferreira MS, Parola, V. Rehabilitation program for elderly to improve physical and cognitive activities using Nintendo Switch: a feasibility study in care settings. Arch Gerontol Geriatr Plus. 2025;2(1):100121.

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