

Training using exergames improves the postural control performance of community-dwelling older adults during dual-task activities

Treinamento usando exergames melhora o desempenho do controle postural de idosos residentes na comunidade durante atividades de dupla tarefa

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Resumo: avaliar o efeito dos exergames no controle postural de pessoas idosas durante tarefas simples (TS) e duplas (TD). Estudo quase experimental com os matriculados na USP60+. Os participantes foram alocados em grupos controle (GC, n=15, 66,5±6,3 anos, 73,3% mulheres) e treinamento (GT, n=16, 67,1±4,6 anos, 71,2% mulheres). Antes e após a intervenção, a oscilação do centro de pressão (COP) foi registrada durante TS e TD, utilizando uma plataforma de força portátil. O treinamento foi realizado por 12 semanas (2x/sem e 50 min/sessão). Os deltas das variáveis relacionadas ao COP foram calculados e os dados analisados por testes não-paramétricos e pela correlação bisserial (tamanho do efeito). Nível de significância estabelecido foi de $p<0,05$. A oscilação do COP foi maior durante as TD. Houve redução da área do COP (superfície instável + tarefa cognitiva) no GT após o treinamento. A oscilação corporal de pessoas idosas é maior nas tarefas duplas. O treinamento com exergames melhorou a oscilação postural no GT, especialmente, durante atividades de dupla tarefa.

Palavras-chave: Envelhecimento. Equilíbrio. Cognição. Dupla-tarefa. Treinamento em realidade virtual.

Abstract: to evaluate the effect of exergames on postural control in older adults during single (ST) and dual (DT) tasks. A quasi-experimental study involving older adults enrolled in USP60+. Participants were allocated into control (CG, n=15, 66.5±6.3 years, 73.3% women) and training (TG, n=16, 67.1±4.6 years, 71.2% women) groups. Before and after the intervention, the oscillation of the center of pressure (COP) was recorded during ST and DT, using a portable force platform. Training was performed for 12 weeks (2x/week and 50 min/session). The deltas of the variables related to COP were calculated and the data was analyzed by non-parametric tests and biserial correlation (effect size). The significance level was set at $p<0.05$. COP sway was greater during DT, and the COP area (unstable surface + cognitive task) decreased in the TG after training. Body sway in older adults tends to be worse in dual tasks. Training with exergames improved postural sway in the TG, especially during complex dual-task activities.

Keywords: Aging. Balance. Cognition. Exergames. Posture. Xbox.

Introdução

Falls and fall-related injuries are unintentional events commonly observed at older age (MONTERO-ODASSO *et al.*, 2022). As different factors can be involved in a fall, this is considered a complex event and of great risk for older adults, once a single event and its consequences can lead to disability (STEWART WILLIAMS *et al.*, 2015). Although their multifactorial origin, balance disorders are among the main predictors of future events (LI *et al.*, 2022).

As the aging process is associated with physiological changes in the systems responsible for maintaining postural stability (LI *et al.*, 2022), causes of falls are frequently attributed to the inability to recover balance after a postural perturbation. It is important to note that postural stability during static conditions seems to be more preserved with aging, compared with dynamic and high-demand activities (KO; NEWELL, 2016). In this way, scientific evidence on the circumstances of falls shows that these events occur mainly during locomotion (PITCHAI *et al.*, 2019).

During daily living activities, most of the motor tasks are combined with cognitive tasks (i.e., dual-task activities) and in environments with competing sensorial stimuli (TOMAS-CARUS *et al.*, 2019). Carrying out two tasks concurrently leads to competition for attentional resources, so dual-task performance depends on the ability to flexibly manage these tasks, which is commonly reduced in older adults (RAFIEE MANESH *et al.*, 2024). Tomas-Carus *et al.* (2019), for example, observed that the performance of community-dwelling older adults in a walking test (i.e, timed-up and go) reduced when a secondary cognitive task was added.

According to recent world guidelines for fall prevention and management, tailored exercises on balance, gait, and strength are preconized for community-dwelling older adults with low and intermediate risk for falls (MONTERO-ODASSO *et al.*, 2022). In addition, it is also recommended that these exercises support similar movements and tasks required in daily living, which includes not just functional activities (e.g., sit-to-stand, stepping, and walking), but also take into consideration the patterns of movement (i.e, different speeds and directions), the environment and the association with cognitive tasks (i.e, dual-task) (MONTERO-ODASSO *et al.*, 2022).

With advancing technology, exergames have emerged as interactive methods of physical exercises with possible advantages in adherence and reducing cost, since they can be implemented without supervision and in the home environment. In addition to providing stimuli for motor and physical functions, the interaction with this technology can also involve other important abilities, such as sensorial,

cognitive, and psychological (COSTA *et al.*, 2019).

Therefore, the present study aimed to examine the effect of exergames training on the postural control performance of older adults during single and dual tasks. The hypothesis was that intervention with commercially available exergames would improve the standing posture control performance of community-dwelling older adults.

Materials and methods

Study design: this is a quasi-experimental study, uncontrolled, longitudinal, and quantitative, developed at USP60+ of the School of Arts, Sciences and Humanities at the University of São Paulo (EACH/USP).

Participants: community-dwelling older adults enrolled in the regular activities of the USP60+ were recruited. Thirty one older adults were included in the study and allocated for convenience in two groups: control (CG, n = 15) and exergame (EG, n = 16).

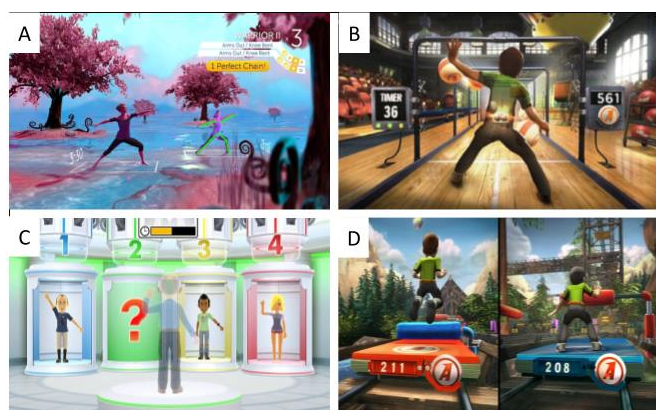
Inclusion and exclusion criteria: older adults 60 years or over, of both sexes, and being an attendant of USP60+, were considered eligible for the study. However, participants were excluded if they have uncontrolled chronic disease (e.g., insulin-dependent diabetes, obesity, cardiorespiratory diseases, neurological diseases, diagnosed vestibular disorders, limiting musculoskeletal disorders and/or dementia), history of recurrent falls, and not being involved in physical conditioning programs (≥ 150 min per week). To ensure that participants have no suggestive signs of dementia, their cognitive performance was assessed by the Mini-Mental State Examination (MMSE), considering cutoff points adjusted for schooling levels.

Experimental procedures and data acquisition: before and after the intervention protocol, the oscillation of the center of pressure (COP) was recorded during the orthostatic position using a portable force platform (BioSway PortableBalance System, Biodex Medical Systems, Shirley, NY). For data collection, each participant was asked to remain for 60 seconds in a bilateral standing position, eyes open, with feet parallel and stably on the platform, during two single-tasks (i.e, quiet standing position on firm and foam surfaces) and four dual-tasks (i.e, standing position plus cognitive or motor tasks on firm and foam surfaces). Participants were oriented to adopt a quiet natural upright position (barefoot, arms along the body, natural parallel position of feet) and looking straight ahead at a white wall. The cognitive task used was the verbal fluency test (VF), which assesses the ability to name the largest possible number of words from the same semantic category within 60 seconds (animals, fruits, etc.). This test evaluates attention, semantic memory, executive functions, and language. As a

motor task, the submaximal voluntary isometric contraction was used, in which the participants should maintain an isometric contraction (i.e. hand grip) of the dominant arm at an intensity of 30% of the maximum contraction (previously tested) for 60 seconds. For this task, the tested arm was positioned with the shoulder in a neutral position, the elbow flexed at 90°, and the forearm and wrist in a neutral position.

Training protocol: Exergame training was performed twice a week, during 50 min/sessions, and for 12 weeks. Different games of kinetic sensors for Microsoft Xbox 360 were used for the exergame training. The training sessions were offered in pairs, to stimulate the performance of the older adults during playing, which might also have contributed to the stimulation of mechanisms responsible for the suppression of irrelevant information (partner movement and sharing the game screen). At each session, games involving both motor tasks (limb movements, displacement of the center of gravity, and changes in the base of support) and, as well, cognitive tasks (calculations, memory, logic, and reasoning) were used. Game intensity/difficulty were increased when available in the game and/or when the volunteers were able to complete initial levels easily and with no complaints. Examples of games used are presented in figure 1.

Figure 1 | Examples of games used in training sessions.



A - yoga (Your Shape Fitness Evolved 2012); B - coordination and changes in base of support (Kinect Adventures); C - memory and limb movements (Dr. Kawashima's Body and Brain Exercises); D: jump, squat and changes in base of support (Kinect Adventures). Source: own authorship

Data analysis: The collected data were transferred to specific software (Patient Data Collection, Version 2.0.1, Biodex Medical Systems, Inc.) and then saved in a text file (.txt) for further analysis. Data was acquired at a sampling frequency rate of 20 Hz. Each condition evaluated in the present study generated a data sequence with two columns (X,Y), which represented COP displacement in the mediolateral (ML) and anteroposterior (AP) directions, respectively. The data were then treated in a Matlab environment (Mathworks, Inc), through a specific routine (MAGALHÃES; KOHN, 2014). So, the following dependent variables were obtained for all conditions tested: 1) statokinesiogram area (Area, mm²), calculated from obtaining an ellipse encompassing 95% of the COP data; 2) mean velocity (MV, mm/sec), calculated by dividing the total COP displacement (in mm) by the total time

(in sec), in the AP and ML directions; and root mean square (RMS, mm), equivalent to the standard deviation of the COP displacement, also calculated in the AP and ML directions. Statistical analyses were performed using the SPSS software. Categorical variables are expressed as absolute (n) and relative (%) frequencies. The differences between groups for categorical variables were evaluated using Pearson's chi-square and Fisher's exact tests. For continuous variables, Shapiro-Wilk and Levene tests were used to test the assumption of normality and homogeneity, respectively. For the comparison of the participant's characteristics in basal condition, the Student's t-test for independent samples was used. Delta values of all COP variables were calculated by subtracting post from pre-results. Differences between groups for COP variables at baseline were assessed by Mann-Whitney. The overall effects of the group, surface, and task on delta values were evaluated using the Mann-Whitney and biserial correlation to effect size. The Kruskal-Wallis test was used to determine the condition causing the differences between the two groups. For all analyses, the significance level was set at $p < 0.05$.

Ethical aspects: the study was approved by the Ethics Committee Board of the EACH/USP (protocol number: 216.164) and all participants signed informed consent.

Results

Sociodemographic characteristics, anthropometric variables, history of falls, and MMSE scores of both groups at baseline are presented in Table 1. There was no violation of distribution and homogeneity for all continuous variables. No statistical differences between groups were observed.

At baseline, no differences for all COP variables were observed. So, the effects of the exergames on the postural oscillation at different surfaces and during different tasks were evaluated after the delta calculation. Group effects were observed for Δ Area ($U = 3096.0$, $z = -3.34$, $p = 0.001$), Δ RMSap ($U = 3269.0$, $z = -2.86$, $p = 0.004$), Δ Vap ($U = 3531.5$, $z = -2.15$, $p = 0.032$) and Δ Vml ($U = 2725.0$, $z = -4.35$, $p < 0.001$). On the other hand, no effects of surface and task were found for all delta variables. The effect sizes of the differences between the control and exergame groups were medium for Δ Area ($d = -0.51$) and Δ Vml ($d = -0.67$). For the other measures (i.e., Δ RMSap, Δ RMSml, and Δ Vap), the effect sizes were small. Among all conditions tested, only Δ Area of the COP during the cognitive task on foam surface was significantly ($H_{(1)} = 6.81$, $p = 0.009$) lower in the exergame group compared to the control group. This result indicated that the participants of the exergame had a better postural response at the follow-up, especially during the cognitive dual-task on an unstable surface. On the same way, the COP oscillation in the mediolateral direction (i.e., Δ RMSml) differed significantly between groups during the standing quiet ($H_{(1)} = 6.81$, $p = 0.009$) and motor dual task ($H_{(1)} = 3.91$, $p = 0.048$) on foam. Differences between groups were also observed for the velocity of COP oscillation in the mediolateral direction (i.e., Δ Vml) during cognitive ($H_{(1)} = 5.62$, $p = 0.018$) and motor dual

task ($H_{(1)} = 4.56$, $p = 0.033$), but only on the firm surface. The oscillation (ΔRMS_{ap}) and the velocity (ΔV_{ap}) of the COP in the anteroposterior direction were not different between groups for all conditions tested.

Table 1 | Baseline characteristics of the participants.

Variables	Control (n = 15)	Exergame (n = 16)	Statistics
Age (years)	66.3 (6.0)	66.0 (4.5)	$t_{(29)} = -0.30$, $p = 0.77$, $d = -0.11$
Female	11 (73.3)	13 (81.3)	$\chi^2 = 0.009$, $p = 0.92^*$
Schooling level			
1 - 4 years	2 (13.3)	3 (18.8)	
5 - 8 years	2 (13.3)	4 (25.0)	$\chi^2_{(2)} = 1.04$, $p = 0.60^*$
> 8 years	11 (73.3)	9 (56.3)	
Height (m)	1.61 (0.08)	1.56 (0.08)	$t_{(29)} = 1.23$, $p = 0.44$, $d = 0.44$
Weight (kg)	74.3 (13.4)	64.7 (2.3)	$t_{(29)} = 1.99$, $p = 0.44$, $d = 0.71$
BMI (kg/m ²)	28.4 (3.2)	26.6 (4.3)	$t_{(29)} = 1.54$, $p = 0.13$, $d = 0.55$
Fall history			
Yes	3 (20.0)	5 (31.2)	
No	12 (80.0)	11 (68.8)	$\chi^2 = 0.09$, $p = 0.76^*$

Data are reported as mean (SD) for continuous variables or frequency (percentage) for categorical variables. *Fisher's Test. BMI: body mass index. Source: own authorship.

Discussion

The present study investigated the effects of exergames on the postural control of community-dwelling older adults. The training protocol improved the postural control of the older adults, evidenced in this work by the displacement of the COP in the mediolateral direction, mainly during the complex primary task (i.e., postural control on foam surface). As some improvements were observed even during dual-task performance, this type of training has the potential to positively impact postural stability during activities of daily living.

Standing position is often associated with other simultaneous tasks, such as reading, talking, holding objects, and making decisions, which are essential for independent living. To effectively carry out most activities of daily living, posture must be managed to support both an upright position and the successful completion of tasks (O'NEILL *et al.*, 2024). In other words, for postural balance to be maintained, the individual's center of mass must be within the base of support and, therefore, not exceed the limit of postural stability. Postural control declines with age, primarily due to age-related changes in various systems that contribute to maintaining postural balance (LI *et al.*, 2022).

Different studies have shown that body sway characteristics, assessed through the measures of COP displacement under different conditions, change with increasing age (ABRAHAMOVÁ; HLAVACKA, 2008; RAFIEE MANESH *et al.*, 2024). Among the parameters associated with COP displacement, different studies suggested that differences between older and young adults in postural stability and balance activity can be detected by distance-related (range and area of COP oscillation) and velocity measures, respectively (ABRAHAMOVÁ; HLAVACKA, 2008; DEGANI; LEONARD; DANNA-DOS-SANTOS, 2017). In other words, distance-related measures are associated with the effectiveness of the postural control system in reaching stability, while velocity measures are related to the amount of regulatory activity needed to the level of stability reached (ABRAHAMOVÁ; HLAVACKA, 2008; FUJIO; TAKEUCHI, 2021).

Degani, Leonar, and Danna-Dos-Santos (2017) speculated that older adults depend on the feedback mechanisms rather than the feedforward mechanisms to maintain postural stability. Therefore, age-related changes in sensorimotor integration may lead to alterations in postural correction patterns, resulting in larger and faster postural sway as age increases. In literature, there is evidence suggesting that age-related differences in postural control of the COP are more evident in the sagittal plane than in the frontal plane, confirmed by the increase of some AP-related parameters (ABRAHAMOVÁ; HLAVACKA, 2008; DEGANI; LEONARD; DANNA-DOS-SANTOS, 2017; FUJIO; TAKEUCHI, 2021).

On the other hand, some authors argue that changes in COP displacement occur in both directions with aging. This is supported by a meta-analysis of Roman-liu, in which differences in COP displacement range between two age groups (i.e., 18 - 35 years old vs. ≥ 56 years old) varied from 20 to 30% for AP and 40 to 50% for ML (ABRAHAMOVÁ; HLAVACKA, 2008; RAFIEE MANESH *et al.*, 2024; ROMAN-LIU, 2018), while COP velocity varied from 30 to 50% for both AP and ML direction, depending on the presence of vision input. Liang *et al.* (2022) also observed that most of the COP parameters were significantly different between the healthy younger and older groups, being the mean velocity in the AP and ML directions effective in discriminating age-related changes (LIANG *et al.*, 2022). Independently of the discrepancy among studies, the evaluation of the age-related effect on postural control, which is commonly exacerbated in highly sensorial or cognitively demanding situations, is important to rehabilitation and geriatric fields (ABRAHAMOVÁ; HLAVACKA, 2008; ROMAN-LIU, 2018).

Considering the complexity of the mechanisms involved in postural control, it is important to assess it when older adults face different stimuli, including cognitive and motor tasks (BRUSTIO *et al.*, 2017; ZHOU *et al.*, 2023). Age-related changes in cognition, especially inefficient suppression of irrelevant information, can influence functional performance

in dual-task situations. This becomes more apparent when working memory is heavily taxed by processing two tasks simultaneously (RAFIEE MANESH *et al.*, 2024).

In the present study, it was possible to observe greater body sway during dual tasks on an unstable surface, which suggests the influence of the complexity of the primary task on the postural response to the addition of a second simultaneous activity. In an attempt to explain the reduction in performance during dual tasks, some authors defend the cortical hypothesis, in which the worsening of performance may be due to the concomitant use of the same neuronal resources, thus generating impairment in the performance of activities (DE ROND *et al.*, 2021). From this perspective, some authors suggest that this difficulty in performing two simultaneous tasks is partly due to age-related changes in the central nervous system (BEURSKENS; BOCK, 2012).

Adding cognitive elements to exercise programs can benefit older adults, as most daily activities involve multitasking (BRUSTIO *et al.*, 2017). One way to incorporate cognitive elements into an exercise program can be through the use of gaming technology. Videogames are promising tools for exercise, as they encourage regular activity adherence and can be practiced at home (CALDEIRA DE MELO, 2019). They also offer interactive visual experiences that engage the user deeply with the screen. Games can be selected according to each person's abilities, in addition to enabling the creation of challenging environments. Studies have also shown that when it is adapted to the particularities of the target population, high learning rates are observed, thus offering the possibility of personal and residential use of the video game for physical conditioning purposes (CARDONA *et al.*, 2023)

With the advent of video games equipped with motion sensors, numerous studies have focused on their use for rehabilitation and physical training. In older adults, studies involving exergames have shown that exergames are not superior to conventional exercise to improve physical and cognitive performance (CHEN *et al.*, 2023). Compared to non-exercise interventions (such as control groups or educational programs), exergames have enhanced balance and mobility in healthy older adults and motivated patients to adhere to their exercise regimes (PACHECO *et al.*, 2020).

Therefore, using new technologies based on video games can serve as a potential alternative to enhance not only physical function but also cognition and dual-task performance in older adults (OGAWA; YOU; LEVEILLE, 2016). A systematic review revealed that older adults may develop greater attention after dual-task training, which, in turn, can improve external information processing. So, older adults would react more quickly to sudden disturbances (PICHIERRI *et al.*, 2011).

The results of the present study are partially consistent with previous studies, as the improvement was only observed during dual tasks where the primary activity was more complex (unstable surface). LAUFER, DAR & KODESH (2014)

conducted a systematic review to assess the effects of exergames on balance and functional performance in older adults. Of the seven studies included, three reported positive effects of exergames on postural sway measures (LAUFER; DAR; KODESH, 2014), which corroborates the findings of the present study

The present study has some limitations that need to be highlighted. The first consideration refers to the small number of older adults and the lack of randomization of the sample. It is worth mentioning that the majority of the older participants had a history of participating in other physical and cognitive activities, which may have influenced the results of this study.

Conclusion

Body sway in older adults tends to be worse in dual tasks, especially in those where the primary task is more complex (unstable surface). Physical training with exergames, in turn, improved postural sway in the trained group, with results only observed during the performance of dual-task activities.

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