Journal of Physical Education and Sport ® (JPES), Vol 19 (Supplement issue 3), Art 120, pp 833 - 840, 2019
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Effect of Exergames on Physical Function, Cognitive Capacity, Depressive State and Fall-Risk in Mexican Older Adults: A pilot study

LUIS M. GÓMEZ-MIRANDA[1], NOÉ SANTIAGO-LÓPEZ[2], YAMILETH CHACÓN-ARAYA[3], JOSÉ MONCADA-JIMÉNEZ[4], AND MELINNA ORTIZ-ORTIZ[5]
[1,2,5,]Sports Faculty, Autonomous University of Baja California, Tijuana, MÉXICO
[3,4,]School of Physical Education and Sports, University of Costa Rica, COSTA RICA

Published online:May 31, 2019
(Accepted for publication March 25, 2019)
DOI:10.7752/jpes.2019.s3120

Abstract:
Introduction: By the year 2050, the Mexican older adult population rate will triple, and consequently, there will be an imperative need to offer to this aging group a better quality of life, including maintaining their functional and cognitive autonomy. **Purpose:** To determine the effects of exergames on physical function, cognitive capacity, depressive state and fall-risk in Mexican older adults. **Methods:** In a quasi-experimental design, 14 older adults were divided into an experimental (EG, n = 7) and a control (GC) group. Exergames and physical conditioning exercises were performed for 15-weeks by participants in the EG. Measures of physical function (Senior Fitness Test, SFT), cognitive capacity, depressive state, and fall-risk were obtained before and after the intervention. Dependent variables were analyzed by general linear-model ANOVA tests (2 groups x 2 measurements). **Results:** Significant interactions were found between groups and measurements in SFT upper-body flexibility ($p = 0.041$) and agility scores ($p = 0.007$). The EG reduced pre- to post-test agility times (7.71 ± 1.54 vs. 6.39 ± 1.78 s, $p = 0.010$). **Conclusions:** Physical activity in combination with exergames is a feasible and effective strategy to improve flexibility and agility in older adults. The use of technologies is an attractive and effective tool to promote health and avoid physical deterioration in Mexican older adults.
Key Words*:* Videogames, elderly, fitness, cognitions, depression

Introduction

The older adult population has grown more than any other age group; this might be explained by a decrease in birth rate and an increase in life expectancy (World Health Organization, 2015). Mexico is also experiencing a demographic aging. According to the epidemiological profile of the elderly in Mexico, in the year 2000, people aged 60 and older represented 6.8% of the total population, and an increase of 28% was expected by the year 2050 (National Epidemiological Surveillance System, 2011); and only in Baja California State, there were 183,577 inhabitants 65 yr. old and older (Men = 46.3%, Women = 53.7%). Data from a census in Baja California's cities of Mexicali and Tijuana municipalities in 2015, showed the highest cluster of older adults above 65 yr., especially women (Government of the State of Baja California, 2014). In Tijuana, there were 78,019 inhabitants over 65 yr.; with a projected population by 2020 of 101,574, and 176,134 inhabitants by 2030 (Government of the State of Baja California, 2014). The healthy life expectancy of the Mexican older adult is 65.8 yr. (Manrique-Espinoza et al., 2013). This means that if the population's life expectancy in general is 74.4 yr., the population meeting that age is at increased risk of developing some disease or dependence during approximately nine years of their life. For the population over 60 yr., the three most frequent health conditions reported were hypertension (40.0%), diabetes (24.3%) and hypercholesterolemia (20.4%) (National Epidemiological Surveillance System, 2011). These diseases affect all body systems and prevent them from carrying out daily life activities such as walking, eating, preparing or buying food, and bathing, among others. Therefore, older adults are negatively affected, not only physically, but also psychologically and socially.

In this context, there are essential reasons to create innovative behavioral changes to reduce the mortality rate in the older adult population and improving their quality of life. It is believed that this can be achieved if a healthy lifestyle is acquired, which includes healthy eating and practicing daily physical activity (Petretto, Pili, Gaviano, Matos López, & Zuddas, 2016). The continuous growth of the older population has launched several strategies aimed at improving their quality of life (Alonso Galbán, Sansó Soberats, Díaz-Canel Navarro, Carrasco García, & Oliva, 2007). Among the strategies used to increase physical activity are the combination of video games and physical exercise, also known as exergames (Garcia Marin, Felix Navarro, & Lawrence, 2011). In this case, the use of the video game is targeted directly at increasing physical activity with the aim of improving muscle strength, balance, flexibility and agility in the older adult (de Rosario Martínez et al., 2013). Exergames have also shown evidence of improving cognitive processes such as logic reasoning, executive function, attention, spatial cognition, perception, and balance (Madrigal-Pana, Gómez-Figueroa, &

Corresponding Author: MELINNA ORTIZ-ORTIZ, E-mail: melinna.ortiz@uabc.edu.mx

Moncada-Jiménez, 2018; Stanmore, Stubbs, Vancampfort, de Bruin, & Firth, 2017; van Diest, Lamoth, Stegenga, Verkerke, & Postema, 2013).

Bieryla (2016) determined the impact of the Xbox Kinect system on the balance in 13 older adults. The participants in the experimental group trained using Kinect three days a week for three weeks, and the control group continued their normal activities. The experimental group improved their balance, while the control group did not. The authors concluded that using exergames might represent an economic and feasible tool to improve balance in older adults and that the protocol can be continued at home (Bieryla, 2016). Lee and Shin (2013), conducted a study to determine whether a virtual reality (VRE) program improves balance, gait, muscle strength and risk of falling in older adults with diabetes. The participants were 55 older adults with type 2 diabetes mellitus, who were randomly assigned to a control or an experimental group. The control group received diabetes education sessions and the experimental group performed the VRE program consisting of video games played on a PlayStation-2® console for 50-min, two-days a week for 10-weeks. At the end of the intervention, improvements in the experimental group were observed on balance, sitting-to-stand times, walking speed, walking cadence and a reduction in the risk of falls. The authors concluded that the VRE program maximizes the effects of exercise, and suggest that VRE programs are feasible and effective in reducing the risk of falls in older adults with type 2 diabetes.

Brox, Konstantinidis, and Evertsen (2017), studied the adherence to exergames in older adults, as well as their motivations to play. Seven older adults with an average age of 80 yr. participated in the study, and were required to play for five months with the exergames using the Wii Sports platform and Wii fit plus. The participants not only liked the balance board and argued that it improved their balance, but also enjoyed the table tilt game. The jogging game was also popular, and after five months of playing, four participants reported that they could improve their endurance. The main conclusions were that the enthusiasm presented at the end of the five months would suggest that older adults would continue exercising for an extended period since this type of activity causes adherence and motivation (Brox et al., 2017). Uzor and Baillie (2014) studied 17 older adults to determine the effects of using exergames on the adherence to a fall rehabilitation program and to determining the effects on physical functioning and balance. The sample was divided into a control (n = 9) and an experimental group (n = 8). Results indicated that exergames were highly accepted and shows a potential to improve mobility.

This type of physical activity has different effects; however, its cognitive and emotional effects are unclear in Mexican older adults. Therefore, the purpose of this study was to determine the effect of a physical exercise program with exergames on functional and cognitive capacity, depressive state and fall-risk in Mexican older adults.

Material & methods

Design and Participants

The research design was quasi-experimental, with a control (CG) and an experimental (EG) group, and pre- and post-test measures. A convenience sample of 14 older adults were located into the EG (n = 7) and CG (n = 7). The inclusion criteria were that volunteers had 60 yr. of age or above, being able to practice physical activity (assessed by the PAR-Q), did not suffer from a disability that prevented them from having the total mobility of their limbs. In addition, volunteers had to meet adequate vision to distinguish videogames and perform all the initial evaluations. The dependent variables were body height and weight, body mass index (BMI), functional physical condition, cognitive capacity, depressive state and risk of falling. All participants signed a voluntary informed consent letter where the characteristics of the study were explained and that they were free to withdraw from the study at the time.

Measurement Instruments

The body height (cm) was assessed with a SECA, model 213 (Chino, CA, USA) portable stadiometer. For the maximum height the person was standing, barefoot, with the feet together, knees extended, back in contact with the vertical piece of the measuring device, the arms at the sides with the palms directed towards the thighs with the head placed in the Frankfurt plane to show the vertex (the most prominent and high part of the head). The participants were instructed to hold a deep breath while keeping the head still. An assistant firmly placed a square (stadiometer) on the vertex. The measurement was taken at the end of the traction and deep inspiration. The body weight (kg), body fat percentage (%), lean mass (kg), visceral fat (kg) and metabolic age (yr.) were assessed with an electronic Tanita scale (Tanita Corp. Tokyo, Japan). The measurement was made without shoes with light clothing, placed the subject on top of the scale without leaning on any other site. The BMI (kg/m^2) was computed as follows: body weight (kg)/body height $(m)^2$.

The functional physical condition was evaluated with the Senior Fitness Test (SFT) (Rikli & Jones, 2013). The lower-body strength (SFT-LBS) was assessed by the 30-s test of getting up and sitting down from a chair. The upper-body strength (SFT-UBS) was evaluated by the 30-s arm curl with a dumbbell (men = 8-lb, women = 5-lb). Lower-body flexibility (SFT-LBF) was assessed by the chair flexion test, where participants slowly flex the hip joint, reaching as much as possible or surpassing the toes. Upper-body flexibility (SFT-UBF) was assessed by the hands test behind the back. The distance between the tips of the middle fingers was assessed independently of the alignment of the back. Agility was assessed by the 2.44 m timed-up and go test (SFT-

TUG), where participants had to get up of a chair, walk as fast as possible 2.44 m and sit down again. Aerobic resistance was evaluated by the 2-min standing marching test (SFT-marching), where participants had to perform as many repetitions (reps) as possible (Rikli & Jones, 2013).

Cognitive capacity was assessed with the Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975). The MSSE consists of a cognitive screening for older adults that examines eight cognitive domains (orientation, attention, calculation, visuospatial ability, language, constructive ability, immediate and delayed memory). The depressive state was evaluated with the Geriatric Depression Scale (GDS) (Yesavage et al., 1982), a hetero-administered questionnaire consisting of 15 questions used for the screening of depression in older adults. The risk of falling was evaluated by means of gait and balance scores from the Tinetti Balance Assessment Tool (TBAT) (Tinetti, Williams, & Mayewski, 1986). The older adult is required execute exercises of marching and balance. The maximum score of the walking subscale is 12 and 16 for the balance subscale. The sum of both scores assessed the risk of falls, the higher the score, the lower the risk of falling.

Procedures

The study procedure was divided into four stages. In the first stage, participants were contacted through a personal invitation. The intervention program was explained, and participants were asked about possible health conditions. Those agreeing to participate in the study were given explanations about the ethical implications and were asked to sign the informed consent. In the second stage, the initial evaluations (i.e., pre-test) of the dependent variables were carried out in the order described above. The intervention program was performed in the third stage. The members of the EG carried out a program of physical activity combined with exergames. The intervention lasted 15-weeks, three-times a week (Monday, Wednesday and Friday), with a duration of 120-min. Each session consisted three phases. The goal of the first phase was to perform exercises to increase the body temperature, increase joint movement and muscle stretching. The duration of the phase was ~15-min. The second phase lasted ~45-min as was considered the main part; and consisted in playing exergames with the Xbox-360 console and the Kinect Sensor. The image projection was projected to a wall (Epson S10 projector of 2600 lumens with a resolution of 800 x 600 pixels, with monophonic internal sound). The exergames played were Kinect Sport, Kinect Sport Season Two, and Kinect Adventures. At the end of this activity, participants performed 45-min of general physical conditioning using most of their functional capacities, such as strength, endurance, speed and flexibility. The third phase consisted of a cool-down lasting 15-min. Participants in the CG carried out a weekly physical activity class and joint mobility of low-intensity lasting 40-min. In addition, these participants performed sedentary activities such as reading and conversations on diverse topics. The final stage involved dependent variable measurements (i.e., post-test) following the 15-week intervention.

Statistical analysis

Statistical analyses were performed with the IBM-SPSS Statistics, version 22 (IBM Corporation, Armonk, New York). Descriptive statistics are presented as mean and standard deviation (M ± SD). General linear-model ANOVA tests (2 groups x 2 measurements) were computed on dependent variables body weight, body height, BMI, body fat %, lean mass, visceral fat, metabolic age, SFT tests, MMSE, GDS and TBAT. Eta squared (η^2) was computed as an estimate of effect size. Post hoc analyzes were performed when significant interactions were found. The level of significance was set *a priori* at $p \leq 0.05$.

Results

Descriptive statistics for the EG and CG before and after the intervention is presented in table 1.

Table 1. Descriptive statistics (M ± SD) for experimental and control group before and after interventions (n = 14).

	Experimental Group (n = 7)		**Control Group (n = 7)**	
Variable	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**
Age (yr.)	65.43 ± 6.45	-	65.14 ± 11.45	-
Weight (kg)	71.13 ± 10.98	71.19 ± 11.30	69.47 ± 12.41	73.17 ± 13.45
Height (cm)	152.53 ± 9.03	152.76 ± 8.76	153.11 ± 4.08	152.64 ± 3.87
BMI (kg/m^2)	30.7 ± 5.4	30.7 ± 6.0	29.8 ± 6.3	31.6 ± 6.8
Body fat (%)	41.27 ± 12.76	45.86 ± 9.58	45.20 ± 7.36	47.77 ± 8.40
Lean mass (kg)	21.64 ± 5.06	20.69 ± 6.67	26.51 ± 5.67	23.80 ± 7.27
Metabolic age (yr.)	70.57 ± 9.57	67.86 ± 9.94	62.57 ± 8.18	68.71 ± 10.95
Visceral fat (kg)	12.71 ± 2.21	13.29 ± 2.75	10.86 ± 2.12	10.71 ± 2.50
SFT-LBS (reps)	11.29 ± 1.80	12.29 ± 1.98	8.86 ± 2.19	8.86 ± 1.86
SFT-UBS (reps)	14.71 ± 5.31	17.00 ± 6.88	13.29 ± 6.52	13.14 ± 2.80
SFT-LBF (cm)	-0.43 ± 5.47	0.71 ± 4.95	-2.50 ± 4.23	-2.14 ± 6.44
SFT-UBF (cm)	-18.71 ± 9.46	-9.71 ± 14.78	-11.71 ± 6.40	-13.86 ± 7.22
SFT-TUG (s)	7.71 ± 1.54	6.39 ± 1.78	6.70 ± 1.22	7.56 ± 0.90
SFT-marching (reps)	76.86 ± 20.68	95.00 ± 19.46	59.14 ± 20.62	65.14 ± 38.66
MMSE (pts)	27.29 ± 2.63	28.43 ± 0.98	27.00 ± 1.73	26.43 ± 0.79
GDS (pts)	3.86 ± 3.24	3.00 ± 2.94	4.00 ± 2.00	3.00 ± 2.00
TBAT (pts)	23.29 ± 1.50	23.86 ± 3.34	22.86 ± 3.39	23.14 ± 2.04

Note: SFT = Senior Fitness Test; LBS = Lower-body strength; UBS = Upper-body strength; LBF = Lower-body flexibility; UBF = Upper-body flexibility; TUG = Timed-up and go test; MMSE = Mini-Mental State Examination; GDS = Geriatric Depression Scale; TBAT = Tinetti Balance Assessment Tool; reps = repetitions; pts = points.

Inferential statistics showed significant group by measurement interactions on SFT-UBF ($p = 0.041$, $\eta^2 = 30.5\%$, Fig. 1-A), and SFT-TUG ($p = 0.007$, $\eta^2 = 46.8\%$, Fig. 1-B); however, for the SFT-UBF no significant differences were detected in the post-hoc analysis. SFT-TUG post hoc in the EG showed a better performance from pre- to post-test (7.71 ± 1.54 vs. 6.39 ± 1.78 s; $p = 0.010$).

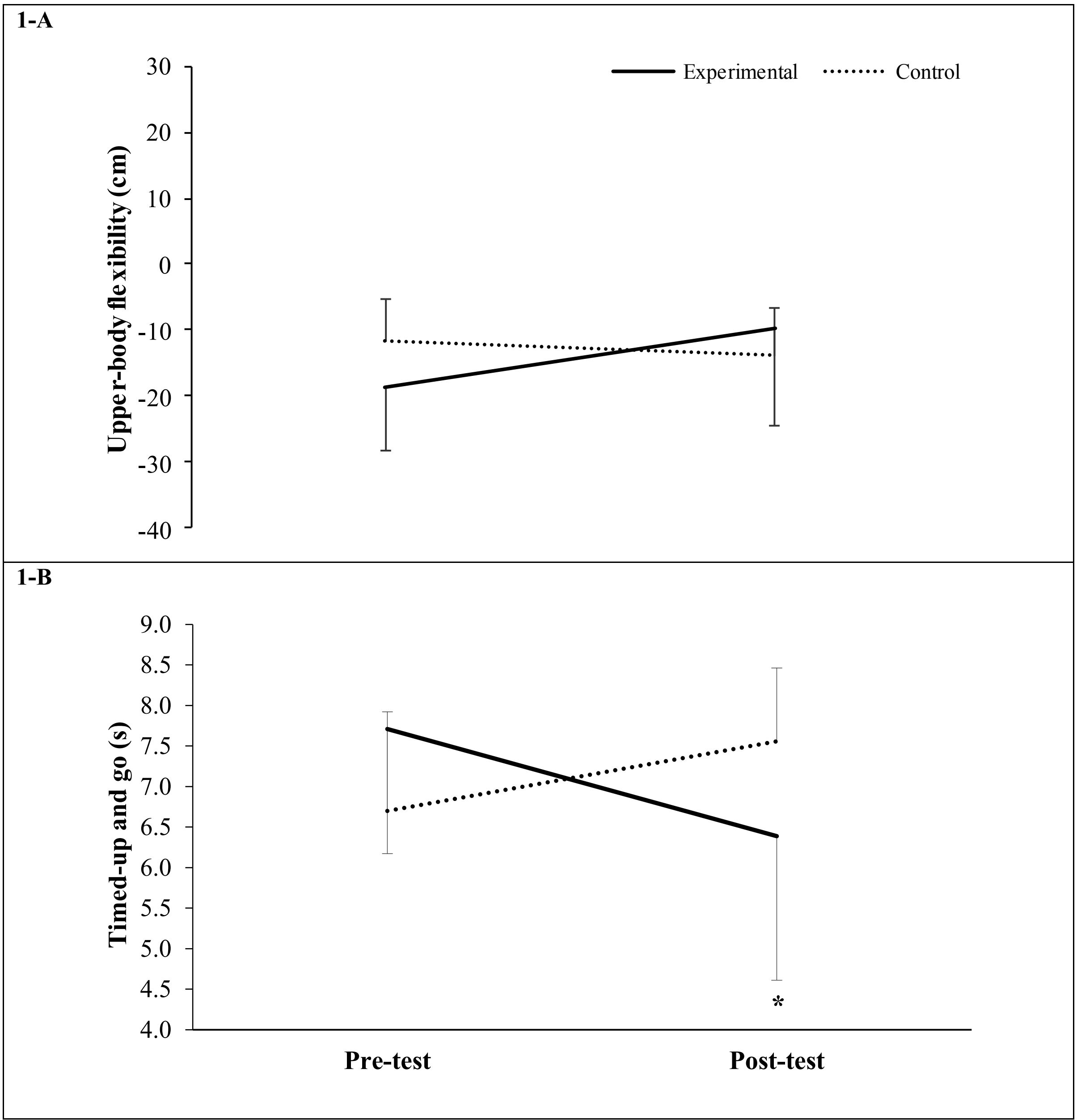

Fig. 1. Group by measurement interaction on the Senior Fitness Test of upper-body flexibility (Panel 1-A), and Senior Fitness Test of timed-up- and go (Panel 1-B). *p = 0.010 for the difference between pre- to post-test in the experimental group.

No significant group by measurements interactions in body weight ($p = 0.290$, $\eta^2 = 9.2\%$), body height ($p = 0.078$, $\eta^2 = 23.7\%$), BMI ($p = 0.143$, $\eta^2 = 17.0\%$), body fat ($p = 0.698$, $\eta^2 = 1.4\%$), lean mass ($p = 0.359$, $\eta^2 = 7.0\%$), visceral fat ($p = 0.304$, $\eta^2 = 8.8\%$), metabolic age ($p = 0.060$, $\eta^2 = 26.5\%$). Also, no significant interactions were found on SFT-LBS ($p = 0.173$, $\eta^2 = 14.9\%$), SFT-UBS (0.412, $\eta^2 = 5.7\%$), SFT-LBF ($p = 0.740$, $\eta^2 = 1.0\%$), SFT-marching ($p = 0.271$, $\eta^2 = 10.0\%$), MMSE ($p = 0.261$, $\eta^2 = 10.4\%$), GDS ($p = 0.866$, $\eta^2 = 0.2\%$), and TBAT ($p = 0.870$, $\eta^2 = 0.2\%$).

Significant main effects were found in SFT-LBS ($p = 0.012$, $\eta^2 = 42.1\%$), SFT-marching ($p = 0.041$, $\eta^2 = 30.5\%$), and GDS ($p = 0.045$, $\eta^2 = 29.5\%$). Regardless of the initial and final measurements, the EG had higher mean values in the variable SFT-LBS than the CG (11.79 ± 0.70 vs. 8.86 ± 0.70 rep). Regardless of the group, the initial measurements were lower than the final measurement in the SFT-marching (68.00 ± 5.52 vs. 80.07 ± 8.18 reps), and the initial measurements were higher than the final measurement in the GDS (3.93 ± 0.72 vs. 3.00 ± 0.67 pts).

Discussion

In this study, we determined the effects of exergames and a general fitness program on physical function, cognitive capacity, depressive state and fall-risk in Mexican older adults. The main finding was a significant improvement in agility and upper-body flexibility following a physical activity program in combination with exergames. This finding is consistent with other evidence in older adults showing that physical exercise programs combined with exergames improve physical function, including flexibility (Chao, Scherer, & Montgomery, 2015; Choi, Guo, Kang, & Xiong, 2017).

The characteristics of this type of interventions, unlike conventional exercise programs, is that exergames include a range of games that demand greater whole body movements in a recreational environment (e.g., sports video games) (Brox, Evertsen, Åsheim-Olsen, Burkow, & Vognild, 2014). Previous and current evidence suggest that older adults report negative perceptions and avoid using technology and videogames (Barg-Walkow, Harrington, Mitzner, Hartley, & Rogers, 2017; Brickfield, 1984; Madrigal-Pana et al., 2018); however, this perception is changed once they understand the goal and content of the game and have enough practice to master it (Barg-Walkow et al., 2017; Bird, Clark, Millar, Whetton, & Smith, 2015; Ferguson, Nielsen, & Maguire, 2017; Hargittai & Dobransky, 2017; Santamaría-Guzmán, Salicetti-Fonseca, & Moncada-Jiménez, 2015). Furthermore, the new term for using technology in the older adult population is "gerontechnology"; and includes the use of video games for health improvement, including physical and cognitive conditions (Lauze et al., 2018; Lauze, Martel, & Aubertin-Leheudre, 2017; Sacco, Thonnat, Sadoun, & Robert, 2018).

In this study, body composition variables remained similar between experimental groups following 15-weeks. Similar results were reported in older adults performing a control exercise (recumbent stationary ergometer) or a virtual reality tours (cybercycle) (Anderson-Hanley et al., 2012). After three months of cybercycling versus traditional exercise, participants showed similar results in body weight, BMI, fat and lean mass, and abdominal fat (Anderson-Hanley et al., 2012). Therefore, research is warranted to determine the best exergame prescription to improve body composition parameters in older adults.

Agility includes a perceptual and decision-making process, with changes in direction and speed (Brughelli, Cronin, Levin, & Chaouachi, 2008). The results of this study show a significant improvement in agility in the experimental group compared to the control group. Other studies have reported improved risk of falling, proprioception and reaction following an exergame program in older adults (Choi et al., 2017; Gschwind et al., 2015). Evidence suggest that to improve agility should be trained along with other motor capacities. Lamoth, Hoekstra, Smid, and Caljouw (2009), conducted a study in older adults who performed an exergame program, showing significant effects on postural control and the variability and stability of trunk accelerations. These capacities are related to the development of agility (Brughelli et al., 2008). Flexibility is also a key physical ability needed to train and improve in the older adult population (American College of Sports Medicine, 2018). Flexibility training in the older adult enhances optimal joint range of motion, postural stability and balance, a set of variables directly related to physical function and reduced risk of falls (Choi et al., 2017; Komatsu et al., 2017; van Diest et al., 2016). The risk of falling plays an important role in the elderly and is directly related to multiple factors such as agility, dynamic balance and cognitive ability; variables that have been improved with the practice of exergame in this population (Grigorova-Petrova, Dimitrova, Lubenova, Zaharieva, & Vasileva, 2015).

In the present study, marching and depressive state showed higher mean scores following 15-weeks; however, there were no significant differences between experimental interventions. The effect size of the time length between initial and final measures for marching and depressive state accounted for ~30% of the variance, and the explained variance interaction terms for both variables was lower than 11%. Therefore, other variables are needed to explain the effects of exergames on motor and psychological constructs. A study reported the effects of a combined physical exercise program with videogames played on a Nintendo-Wii console (Santana et al., 2016), where older adults improved the walking distance traveled following the intervention. These findings reinforce that videogame training represent an alternative to achieve benefits in physical function similar to those reported with other traditional forms of exercises. For example, there has been an increase in gait and joint mobility and a reduction in depressive state in studies using exercise interventions (without exergames) in sedentary older adults (Lorca Navarro, Lepe Leiva, Díaz Narváez, & Araya Orellana, 2011; Pita Díaz & Vergara López, 2009; Rosenberg et al., 2010).

There is an inverse association between gait quality and age; however, evidence has shown that physically active older adults tend to counteract this deleterious condition, and consequently, reducing falling and injury risk (van Diest et al., 2016). This implies that regardless of the type of exercise intervention, an older adult will benefit just by becoming physically active since improvements in gait, depressive and cognitive state are usually observed (Monteiro-Junior et al., 2017).

Older adults often report mood impairment, increased depressive state and lack of motivation, which might be explained by the onset of premature diseases (Catalan-Matamoros, Gomez-Conesa, Stubbs, & Vancampfort, 2016). However, the maintenance of a good state of mental health generates very significant improvements. Therefore, strategies aimed at improving mood state in this age group are of utmost importance. Significant time spent on performing exercise has shown to generate significant reductions in depression in older adults (Catalan-Matamoros et al., 2016; Kok & Reynolds, 2017; Schuch et al., 2016). Furthermore, exergames have been shown to reduce depression in older adults (Li, Theng, & Foo, 2016), which leads to an improved quality of life (Bhamani, Khan, Karim, & Mir, 2015).

The present exploratory study has some limitations. First, the sample size was small; yet, it allowed us to find significant interactions between experimental groups and measurements on two dependent variables (i.e., SFT-UBF and SFT-TUG). Secondly, we did not have a pure control group (i.e., no exercise at all) given the characteristics of the population selected for this study. We followed ethical principles when selecting the study population and some form of exercise could not be denied in the control group. Within the strengths of the study was the 100% retention of the sample and that this was the first exploratory study in the region determining the effects of an intervention program combining exergames and fitness training in older adults.

Conclusions

Physical activity in combination with exergames is a feasible and effective strategy to improve upper-body flexibility and agility in Mexican older adults. Regardless of the type of intervention, an improvement in gait and depressive state was observed between the initial and final measurement. There were no changes in some physical and body composition features, cognitive capacity and balance from pre- to post-test in the two experimental groups. We conclude that using exergames technology is an attractive and effective tool to promote health and avoid physical deterioration in Mexican older adults.

Conflicts of interest – The authors declare no conflict of interest.

References

Alonso Galbán, P., Sansó Soberats, F. J., Díaz-Canel Navarro, A. M., Carrasco García, M., & Oliva, T. (2007). Population aging and frailty of the elderly. *Revista cubana de salud pública, 33*(1), 1-16.

American College of Sports Medicine. (2018). *ACSM's guidelines for exercise testing and prescription* (10th ed.). Philadelhia, PA: Lippincott Williams & Wilkins.

Anderson-Hanley, C., Arciero, P. J., Brickman, A. M., Nimon, J. P., Okuma, N., Westen, S. C., . . . Zimmerman, E. A. (2012). Exergaming and older adult cognition: a cluster randomized clinical trial. *Am J Prev Med, 42*(2), 109-119. doi:10.1016/j.amepre.2011.10.016

Barg-Walkow, L. H., Harrington, C. N., Mitzner, T. L., Hartley, J. Q., & Rogers, W. A. (2017). Understanding older adults' perception of and attitudes toward exergames. *Gerontechnology, 16*(2), 81-90. doi:https://doi.org/10.4017/gt.2017.16.2.003.00

Bhamani, M. A., Khan, M. M., Karim, M. S., & Mir, M. U. (2015). Depression and its association with functional status and physical activity in the elderly in Karachi, Pakistan. *Asian J Psychiatr, 14*, 46-51. doi:10.1016/j.ajp.2014.12.004

Bieryla, K. A. (2016). Xbox Kinect training to improve clinical measures of balance in older adults: a pilot study. *Aging Clinical and Experimental Research, 28*(3), 451-457. doi:10.1007/s40520-015-0452-y

Bird, M. L., Clark, B., Millar, J., Whetton, S., & Smith, S. (2015). Exposure to "Exergames" Increases Older Adults' Perception of the Usefulness of Technology for Improving Health and Physical Activity: A Pilot Study. *JMIR Serious Games, 3*(2), e8. doi:10.2196/games.4275

Brickfield, C. F. (1984). Attitudes and Perceptions of Older People toward Technology. In P. K. Robinson, J. Livingston, J. E. Birren, V. A. Regnier, A. M. Small, & H. L. Sterns (Eds.), *Aging and Technological Advances* (Vol. 24). Boston, MA: Springer.

Brox, E., Evertsen, G., Åsheim-Olsen, H., Burkow, T., & Vognild, L. (2014). *Experiences from long-term exergaming with elderly*. Paper presented at the Proceedings of the 18th International Academic MindTrek Conference: Media Business, Management, Content & Services, Tampere, Finland.

Brox, E., Konstantinidis, S. T., & Evertsen, G. (2017). User-Centered Design of Serious Games for Older Adults Following 3 Years of Experience With Exergames for Seniors: A Study Design. *JMIR Serious Games, 5*(1), e2. doi:10.2196/games.6254

Brughelli, M., Cronin, J., Levin, G., & Chaouachi, A. (2008). Understanding change of direction ability in sport: a review of resistance training studies. *Sports Med, 38*(12), 1045-1063. doi:10.2165/00007256-200838120-00007

Catalan-Matamoros, D., Gomez-Conesa, A., Stubbs, B., & Vancampfort, D. (2016). Exercise improves depressive symptoms in older adults: An umbrella review of systematic reviews and meta-analyses. *Psychiatry Res, 244*, 202-209. doi:10.1016/j.psychres.2016.07.028

Chao, Y.-Y., Scherer, Y. K., & Montgomery, C. A. (2015). Effects of Using Nintendo Wii™ Exergames in Older Adults:A Review of the Literature. *Journal of Aging and Health, 27*(3), 379-402. doi:10.1177/0898264314551171

Choi, S. D., Guo, L., Kang, D., & Xiong, S. (2017). Exergame technology and interactive interventions for elderly fall prevention: A systematic literature review. *Appl Ergon, 65*, 570-581. doi:10.1016/j.apergo.2016.10.013

de Rosario Martínez, H., Ávila Carrasco, C., Ros, F. F., Medina Ripoll, E., Castellano Hernández, W. E., Bollaín Pastor, C., . . . Morales Martín, I. (2013). Improving the users' balance with video-games. *Revista de biomecánica*(59), 31-34.

Ferguson, C. J., Nielsen, R. K. L., & Maguire, R. (2017). Do Older Adults Hate Video Games until they Play them? A Proof-of-Concept Study. *Current Psychology, 36*(4), 919-926. doi:10.1007/s12144-016-9480-9

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-mental state": a practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res, 12*(3), 189-198.

Garcia Marin, J., Felix Navarro, K., & Lawrence, E. (2011). *Serious games to improve the physical health of the elderly: A categorization scheme.* Paper presented at the CENTRIC 2011 : The Fourth International Conference on Advances in Human-oriented and Personalized Mechanisms, Technologies, and Services, Barcelona, Spain.

Government of the State of Baja California. (2014). Population of Baja California and its municipalities. *Apuntes de Población de Baja California, 5*(1), 2-8.

Grigorova-Petrova, K., Dimitrova, A., Lubenova, D., Zaharieva, D., & Vasileva, D. (2015). Feasibility of interactive video games for influence on balance in institutionalized elderly people. *Journal of Physical Education and Sport, 15*(31), 429-432.

Gschwind, Y. J., Schoene, D., Lord, S. R., Ejupi, A., Valenzuela, T., Aal, K., . . . Delbaere, K. (2015). The effect of sensor-based exercise at home on functional performance associated with fall risk in older people – a comparison of two exergame interventions. *European Review of Aging and Physical Activity, 12*(1), 11. doi:10.1186/s11556-015-0156-5

Hargittai, E., & Dobransky, K. (2017). Old dogs, new clicks: Digital inequality in skills and uses among older adults. *Canadian Journal of Communication, 42*(2), 195-212. doi:https://doi.org/10.22230/cjc.2017v42n2a3176

Kok, R. M., & Reynolds, C. F., 3rd. (2017). Management of Depression in Older Adults: A Review. *JAMA, 317*(20), 2114-2122. doi:10.1001/jama.2017.5706

Komatsu, M., Akazawa, N., Tanahashi, K., Kumagai, H., Yoshikawa, T., Kosaki, K., . . . Maeda, S. (2017). Central blood pressure is associated with trunk flexibility in older adults. *Artery Research, 19*, 91-96. doi:https://doi.org/10.1016/j.artres.2017.07.002

Lamoth, C., Hoekstra, W., Smid, A., & Caljouw, S. (2009). Exergaming and balance training. *Gait & Posture, 30*, S144-S145. doi:https://doi.org/10.1016/j.gaitpost.2009.08.216

Lauze, M., Martel, D. D., Agnoux, A., Sirois, M. J., Emond, M., Daoust, R., & Aubertin-Leheudre, M. (2018). Feasibility, Acceptability and Effects of a Home-Based Exercise Program Using a Gerontechnology on Physical Capacities after a Minor Injury in Community-Living Older Adults: A Pilot Study. *J Nutr Health Aging, 22*(1), 16-25. doi:10.1007/s12603-017-0938-8

Lauze, M., Martel, D. D., & Aubertin-Leheudre, M. (2017). Feasibility and Effects of a Physical Activity Program Using Gerontechnology in Assisted Living Communities for Older Adults. *J Am Med Dir Assoc, 18*(12), 1069-1075. doi:10.1016/j.jamda.2017.06.030

Lee, S., & Shin, S. (2013). Effectiveness of Virtual Reality Using Video Gaming Technology in Elderly Adults with Diabetes Mellitus. *Diabetes Technology & Therapeutics, 15*(6), 489-496. doi:10.1089/dia.2013.0050

Li, J., Theng, Y. L., & Foo, S. (2016). Effect of Exergames on Depression: A Systematic Review and Meta-Analysis. *Cyberpsychol Behav Soc Netw, 19*(1), 34-42. doi:10.1089/cyber.2015.0366

Lorca Navarro, M., Lepe Leiva, M., Díaz Narváez, V. P., & Araya Orellana, E. (2011). Efectos de un programa de ejercicios para evaluar las capacidades funcionales y el balance de un grupo de adultos mayores independientes sedentarios que viven en la comunidad. *Revista Salud Uninorte, 27*(2), 185-197.

Madrigal-Pana, J., Gómez-Figueroa, J., & Moncada-Jiménez, J. (2018). Adult Perception Toward Videogames and Physical Activity Using Pokémon Go. *Games for Health Journal, 8*(3). doi:10.1089/g4h.2018.0100

Manrique-Espinoza, B., Salinas-Rodríguez, A., Moreno-Tamayo, K. M., Acosta-Castillo, I., Sosa-Ortiz, A. L., Gutiérrez-Robledo, L. M., & Téllez-Rojo, M. M. (2013). Health conditions and functional status of older adults in Mexico. *salud pública de méxico, 55*, s323-s331.

Monteiro-Junior, R. S., Figueiredo, L., Maciel-Pinheiro, P. T., Abud, E. L. R., Engedal, K., Barca, M. L., . . . Deslandes, A. C. (2017). Virtual Reality-Based Physical Exercise With Exergames (PhysEx) Improves Mental and Physical Health of Institutionalized Older Adults. *J Am Med Dir Assoc, 18*(5), 454 e451-454 e459. doi:10.1016/j.jamda.2017.01.001

National Epidemiological Surveillance System. (2011). *Epidemiological profile of the elderly in Mexico 2010*. Retrieved from México: https://epidemiologiatlax.files.wordpress.com/2012/10/p_epi_del_adulto_mayor_en_mexico_2010.pdf

Petretto, D. R., Pili, R., Gaviano, L., Matos López, C., & Zuddas, C. (2016). Active ageing and success: A brief history of conceptual models. *Revista Española de Geriatría y Gerontología, 51*(4), 229-241. doi:https://doi.org/10.1016/j.regg.2015.10.003

Pita Díaz, G. F., & Vergara López, J. L. (2009). The influence of physical exercise on the health of the elderly: "El Morro" Medical Office, Sucre municipality, Venezuela *Revista de Ciencias Médicas de Pinar del Río, 13*(2), 290-300.

Rikli, R. E., & Jones, C. J. (2013). *Senior Fitness Test Manual*. Champaign, IL: Human Kinetics.

Rosenberg, D., Depp, C. A., Vahia, I. V., Reichstadt, J., Palmer, B. W., Kerr, J., . . . Jeste, D. V. (2010). Exergames for Subsyndromal Depression in Older Adults: A Pilot Study of a Novel Intervention. *The American Journal of Geriatric Psychiatry, 18*(3), 221-226. doi:https://doi.org/10.1097/JGP.0b013e3181c534b5

Sacco, G., Thonnat, M., Sadoun, G. B., & Robert, P. (2018). An approach with serious exergames for assessment and stimulation of patients with neurocognitive disorders. *Gerontechnology, 17*(Suppl), 150s. doi:https://doi.org/10.4017/gt.2018.17.s.146.00

Santamaría-Guzmán, K., Salicetti-Fonseca, A., & Moncada-Jiménez, J. (2015). Learning curve and motor retention of a video game in young and older adults. *Retos*(27), 218-221.

Santana, M., Pina, J., Duarte, G., Neto, M., Machado, A., & Dominguez-Ferraz, D. (2016). Nintendo Wii effects on cardiorespiratory fitness in older adults: A randomized clinical trial. A pilot trial. *Fisioterapia, 38*(2), 71-77. doi:https://doi.org/10.1016/j.ft.2015.03.003

Schuch, F. B., Vancampfort, D., Rosenbaum, S., Richards, J., Ward, P. B., Veronese, N., . . . Stubbs, B. (2016). Exercise for depression in older adults: a meta-analysis of randomized controlled trials adjusting for publication bias. *Braz J Psychiatr, 38*(3), 247-254. doi:10.1590/1516-4446-2016-1915

Stanmore, E., Stubbs, B., Vancampfort, D., de Bruin, E. D., & Firth, J. (2017). The effect of active video games on cognitive functioning in clinical and non-clinical populations: A meta-analysis of randomized controlled trials. *Neuroscience & Biobehavioral Reviews, 78*, 34-43. doi:https://doi.org/10.1016/j.neubiorev.2017.04.011

Tinetti, M. E., Williams, T. F., & Mayewski, R. (1986). Fall risk index for elderly patients based on number of chronic disabilities. *Am J Med, 80*(3), 429-434.

Uzor, S., & Baillie, L. (2014). *Investigating the long-term use of exergames in the home with elderly fallers*. Paper presented at the Proceedings of the 32nd annual ACM conference on Human factors in computing systems, Toronto, Ontario, Canada.

van Diest, M., Lamoth, C. J., Stegenga, J., Verkerke, G. J., & Postema, K. (2013). Exergaming for balance training of elderly: state of the art and future developments. *Journal of NeuroEngineering and Rehabilitation, 10*(1), 101. doi:10.1186/1743-0003-10-101

van Diest, M., Stegenga, J., Wörtche, H. J., Verkerke, G. J., Postema, K., & Lamoth, C. J. C. (2016). Exergames for unsupervised balance training at home: A pilot study in healthy older adults. *Gait & Posture, 44*, 161-167. doi:https://doi.org/10.1016/j.gaitpost.2015.11.019

World Health Organization. (2015). E-Health. Geneva, Switzerland.

Yesavage, J. A., Brink, T. L., Rose, T. L., Lum, O., Huang, V., Adey, M., & Leirer, V. O. (1982). Development and validation of a geriatric depression screening scale: a preliminary report. *J Psychi*