

Effects of Nintendo Wii® Program in Dual-Task Performance in Older Adults

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Abstract

A sedentary lifestyle has a strong impact on the older population; so participation in physical activity is important for enhanced physical and mental function, increasing health and well-being. In the elderly, dual-task activities are severely impaired which is why the Nintendo Wii® may be an important tool to maintain the proper functioning of the physical and mental levels among the elderly. This study sought to determine the effect of Nintendo Wii® training on dual-task performance, cognition, balance confidence, the health status and instrumental performances of daily life activities in older adults. A total of 18 participants aged 75.17±8.86 years were included. All participants were women, retired and living in their own residence. The training included a 15-minute exercise session using Wii®Fit twice a week for 8 weeks. The group was measured before and after the intervention (T0 and T1) and in 3 and 6 months follow-up (T2 and T3). Social demographic factors were assessed at T0 and T3. Cognition, general health status, confidence in balance, performance of instrumental activities of daily life, dual and multi-task performances were assessed at all evaluation moments. The mental component of health status and experimental protocol between T0 and T1 showed a statistically significant improvement. In T2 and T3 interval, there was a significant improvement in mental health status. From the baseline to T1, participants showed a statistical significant improvement in the mental component of health status and in experimental dual-task protocol. It can be concluded that the Nintendo Wii®Fit training program significantly improved dual and multi-task performances among older adults.

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1. Introduction

The impact caused by a sedentary lifestyle is currently evident, especially in the elderly population (WHO, 2011). Participation in regular physical activity contributes to a decrease of disease risk, improves physical and mental function, and creates opportunities of social interaction and greater responsibility for their own health and well-being (Bamidis et al., 2014).

The knowledge that the aging process causes impairment of functionality (Spiriduso & MacRae, 2005) is a challenge for the current society. Physical activity has been demonstrated to be an effective tool able to attenuate or delay the aging process (ACSM, 2009). An effective cognitive processing and a musculoskeletal system that works well are important factors to healthy aging (Roberts, Phillips, Cooper, Gray, & Allan, 2017). With advancing age, many of these systems become damaged and/or weakened, which means that physical capacity of individuals will gradually approach the limit, particularly in activities of daily living, leading to dependence, poor quality of life and increased risk of falls. However, these impairments can be prevented or even partially reversed with exercise (Roberts et al, 2017).

Among the many benefits that physical exercise promotes, the major one is the fomentation of functional capacity of all ages, especially the elderly. Physical activity can improve mental, social and physical functions in the elderly (Roberts et al, 2017; Purath, Keller, McPherson, & Ainsworth, 2013), although it does not increase the lifespan (WHO, 2011). Many of the causes associated with incapacity or decreased functionality in the elderly must be attributed to an absence of stimulation or the nonuse of the physiological functions (Spiriduso & MacRae, 2005).

In normal circumstances, people are able to perform motor and cognitive tasks at the same time, such as walking and talking (Roberts et al, 2017), but the difficulty increases when tasks are done simultaneously, since it uses the same processing pathway information (Walshe, Patterson, Commins, & Roche, 2015). When performed together, these activities in elderly are shown to be severely impaired, which is explained by the fact that cognitive capacity decreases with age and with the loss of automatic engine capacity of the musculoskeletal system (Bergamin et al., 2014).

The activation of brain areas of cognitive control during the task demonstrates the relationship of cognitive functions with motor function (Jehu, Paquet, & Lajoie, 2017) so the dual-task capacity has a great impact in performing daily activities (Halvarsson, Dohrn, & Stahle, 2015). These controls of necessary capacities of attention with the combination of a motor and cognitive task simultaneously decrease with aging (Roberts et al., 2017; Jehu et al., 2017).

The usage of virtual reality has been identified as a low-cost and easily accessible tool (Laver et al., 2012) that allows a degree of control and the challenge over the tasks, incorporating the

feedback provided in real time, which renders it applicable in clinical and rehabilitation environments.

The *exergames* that is a combination of physical activity and deliberate game (Bamidis et al., 2014) allow the player to physically move and interact using the whole body (Barry, Galna & Rochester, 2014; Tore & Raiola, 2012). The advantages of *exergames* compared with conventional programs are that they increase the motivation of the individual to exercise and engage in dual-task activities at the same time, allowing him/her to use and acquire motor and cognitive skills, where the focus is no longer the movement but the feedback moves made during the game (Garcia, Navarro, Schoene, Smith, & Pisan, 2012; van Diest, Lamothe, Stegenga, Verkerke, & Postema, 2013).

The Nintendo Wii® allows the usage of complex tasks that involve extensive neuromuscular coordination and muscle strength, accompanied with online biofeedback (physiological immediate feedback) (Cho, Hwangbo, & Shin, 2014), along with various cognitive tasks (Rendon et al., 2012). The interactivity of this console, in addition to participation, understanding, planning and implementation of appropriate responses to what happens on the screen, requires the individual to use thinking skills (Cho et al., 2014), demonstrating the existence of significant gains in task performance and processing speed (Ackerman, Kanfer, & Calderwood, 2010).

2. Problem Statement

As the aging process occurs, physical and cognitive functions decrease, resulting in reduced dual-task performance in daily life activities. Research has shown that dual-task interventions affects also gait performance, coordination and balance confidence in daily life activities (Cho et al., 2014; Reed-Jones, Dorgo, Hitchings, & Bader, 2012).

3. Research Questions

Can a structured program of exercise using *exergames* be successful in increasing physical and cognitive functions when used by older adults?

4. Purpose of the study

The purpose of this study was to determine the effect of Nintendo Wii® training on dual-task performance, cognition, balance confidence, health status and instrumental performances of daily life activities in older adults.

5. Research Methods

5.1. Participants

Eighteen elderly persons (75.17 ± 8.86 years, range 60-90) were recruited in a small Portugal senior center. All participants were women, retired and living in their own residence. 55.6% of the participants (n=10) were widows and 22.2% (n=4) were married or single. About 44.4% (n=8) of the participants lived alone, 16.7% (n=3) lived with the spouse or sons and 11.1% (n=2) lived with siblings or friends. In terms of educational levels, (3.11 ± 3.98) 50% of the participants had spent less than 3 years in school. In terms of anthropometric characteristics, participants feature BMI (body mass index) (29.04 ± 5.49), where 44.4% (n=8) were in the pre-obese classification, 11.1% (n=2) in obese class I or II, 5.56% (n=1) in obese class III and 27.78% (n=5) were in the normal range. Participants described presence of non-related ADL's (activities of daily living) activities (2.06 ± 1.11), which were the most frequently related with social and religious activities (table 1).

Table 1. Descriptive Characteristics of Participants.

Variable	Total (n=18)	Range (min-max)
Age	75.17 (± 8.86)	60 - 90
Body mass index (kg/m ²)	29.04 (± 5.49)	22.3 - 42.1
Education (years)	3.11 (± 3.98)	0 - 16
Number of daily drugs	4.11 (± 1.99)	2 - 9
Number of referred diseases	0.83 (± 1.20)	0 - 4
Non related ADL's activities	2.06 (± 1.11)	1 - 4

To be included as part of the sample, participants had to be ≥ 60 years old, able to see and hear with or without the adequate means and have no cognition deficit according to educational levels determined by the Mini Mental State Examination. Participants were excluded if they had degenerative conditions affecting the performance, used walking aids, were participating in other physical activity programs in the last 3 months and more than 25% of absences in intervention sessions. Participants who met the selection criteria signed an informed consent form and were not compensated for their participation. The project was approved by a jury of teachers at the College of Health Dr. Lopes Dias of Polytechnic Institute.

5.2. Measures

Sociodemographic information regarding the participants' baseline demographic, social and clinical characteristics was recorded. The cognitive functions of participants were evaluated initially, after 8 weeks and in follow-ups with the Mini Mental State Examination (MMSE) which

includes 19 items to rapidly screen 6 cognitive components: orientation, registration, attention, memory, language and praxis. Total score ranges from 0 to 30 (Folstein, Robins, & Helzer, 1983; Morgado, Rocha, Maruta, Guerreiro, & Martins, 2009). Participants answered a series of questions about general health status (12-Item Short-Form Health Survey [SF-12]) using a physical and mental composite score. The total score is represented on a scale from 0 to 100, with lower scores corresponding to a worse state of health (Ware & Sherbourne, 1992). The Activities-specific Balance Confidence (ABC) Scale was used to assess participant's confidence of their balance during mobility tasks. This scale has 16 items, with answers ranging from 0 (no confidence) to 100 (complete confidence) (Powell & Myers, 1995; Branco, 2010). The Lawton Instrumental Activities of Daily Living (IADL) Scale was used to evaluate the ability to perform instrumental activities of daily living, such as managing finances and arranging transportation. Responses to each of the eight items varies along a range of levels of competence; from independence in performing the activity to not performing it at all. The higher the score, the greater the person's abilities, based on a trichotomous rate method (Graf, 2008).

An experimental protocol was created to evaluate functional performances reported to gait, cognition and coordination in single, dual and multi-task, along a path (6m×0.4m). It includes eight tasks:

- a. Task 1: walk in a straight line
- b. Task 2: walk in a straight line and count backwards
- c. Task 3: walk in a straight line with upper limb coordination
- d. Task 4: walk in a straight line with upper limb coordination and count backwards
- e. Task 5: walk in a straight line and overcome obstacles
- f. Task 6: walk in a straight line, overcome obstacles and count backwards
- g. Task 7: walk in a straight line, overcome obstacles with upper limb coordination
- h. Task 8: walk in a straight line, overcome obstacles with upper limb coordination and count backwards

5.3. Procedures

The participants were assessed before the program (T0) and at the end of the eight weeks (T1). Later, the participants were evaluated at 3 and 6 months (respectively T2 and T3) to measure the evolution of the results accomplished after the 8 weeks' exercise intervention. The same measures used in T0 and T1 were applied in T2 and T3.

The intervention consisted of 15-minute individualized training sessions, 2 times a week for 8 weeks using the Wii®Fit Balance Board. Each session began with warm-up exercises that included upper, lower limb and trunk movements, followed aerobics (“hula-hoop”), balance games (“heading”, “ski jump”, “balance bubble”, “penguin slide”, “zazen”) and training global exercises (“perfect 10”, “tilt city”, “driving range”) and ended with respiratory control in a “yoga” game. The participants did the intervention under the supervision of a physical therapist.

5.4. Statistical Analysis

Results were analyzed using the IBM SPSS Statistics 20.0 for Windows. Measures of central tendency (mean) and dispersion (standard deviation) were applied to variable descriptors. The Wilcoxon signed-rank test was used to compare means at evaluation moments for all outcome measures. This non parametric test was chosen because parametric assumptions of normality and homogeneity were not assumed due to the sample size. A significance level of $P < .05$ was established.

6. Findings

Of the 18 participants of the study, one dropped out in post-intervention evaluation due to a fall episode and another dropped out in the T3 period due to a death in the family (table 2). Between T0 and T1, the intervention showed improvement in the mental component of health status ($P = .009$) and experimental protocol total tasks ($P = .013$). The physical component of health status showed a small improvement, but without statistical significance (table 3). The cognition state and confidence of balance had a small reduction, again without statistical significance (table 2).

Between T1 and T2, there was a continuous improvement of experimental protocol total tasks, mental component of health status and an increase in cognition, confidence of balance and daily living activities, but without statistical significance (table 3).

In T2 and T3 interval, we found an improvement in all variables, still with no statistical significance. Only mental health status showed statistically significant ($P = .023$) improvement.

Table 2. Average of scores reached at each moment of evaluation.

Measure	T0 (n=18)	T1 (n=17)	T2 (n=17)	T3 (n=16)
MMSE	23.94±1.92	23.65±2.60	24.41±3.90	24.88±3.85
ABC Scale	46.60±14.64	41.29±19.36	43.82±20.19	44.00±15.49
IADL Scale	20.00±3.07	18.94±4.05	20.35±2.76	20.06±4.09
Mos - SF-12				
Physical component	32.97±4.84	33.82±6.07	34.56±7.67	33.74±4.87
Mental component	41,42 ± 8.70	46.49±9.91	41.74±7.18	36.16±7.11
Experimental Protocol				
Task 1 Wk	0.06±0.24	0.00±0.00	0.00±0.00	0.00±0.00
Task 2 Wk, Cn	0.67±1.09	0.29±0.99	0.41±0.87	0.88±2.22
Task 3 Wk, Cr	5.67±5.89	5.35±5.95	5.24±5.55	3.69±4.81
Task 4 Wk, Cn, Cr	7.39±7.55	6.53±7.79	6.29±6.47	5.19±5.56
Task 5 Wk, Ob	0.22±0.73	0.06±0.24	0.12±0.33	0.06±0.25
Task 6 Wk, Ob, Cn	2.33±3.13	1.82±2.58	1.29±1.96	1.81±2.93
Task 7 Wk, Ob, Cr	7.22±6.63	6.41±5.52	6.24±6.50	4.13±4.60
Task 8 Wk, Ob, Cn, Cr	9.83±7.67	9.24±8.91	7.35±7.32	7.25±6.31
Total	33.39±30.29	29.71±29.69	26.94±27.10	23.00±21.16

^{Wk} Walk; ^{Cn} Count; ^{Cr} Coordination; ^{Ob} Obstacle

Cognitive and motor dual-task performances of participants, like in tasks 2 and 6, showed an improvement between T0 and T1 (table 2) with no statistical significance (table 3), with a backspace in T3 (table 2). In motor dual-task performances which include simultaneous upper and lower limb motor tasks, like in tasks 3 and 7, we found an improvement (table 2) in all evaluation moments, with statistical significance in task 7 between T1 and T3 ($P = .027$) (table 3). Also evident were multi-task performances as in tasks 4 and 8 which showed an improvement in all situations, with statistical significance in task 8 in T0-T2 ($P = .016$) and T0-T3 ($P = .032$) (table 3).

From the baseline to T3, participants showed a statistically significant improvement in mental health status component ($P = .044$) and in experimental dual-task protocol ($P = .021$).

7. Conclusions

The MMSE scores were compared over the course of the study to determine a change in scores related at each evaluation moment. Overall, the results show that there were no statically significant changes in cognition from baseline to T3 although mean values demonstrate a slight decrease in T0-T1.

This can be justified by the fact that the games used in the intervention are not specifically developed for this area. From T1 till T3, the MMSE score increases but with no statistical significance. A previous study demonstrates that the most significant improvements in cognitive functioning were noted after 23.5 hours of playing in Nintendo Wii®, over a five-week period (Sala, Tatlidil, & Gobet, 2018), which suggests the importance of allowing time for an individual to learn a new skill or adjust to a new task.

Table 3. Statistical significance between each evaluation moment.

Measure	T0/T1	T0/T2	T0/T3	T1/T2	T1/T3	T2/T3
MMSE	.418	.648	.153	.314	.80	.846
ABC Scale	.301	.670	.513	.255	.222	.977
IADL Scale	.032*	1.000	.500	.027*	.021*	.905
Mos - SF-12	.653	.586	.469	.586	.609	.910
Physical component						
Mental component	.009*	.831	.044*	.039*	.002*	.023*
Experimental Protocol	.317	.317	.317	1.000	1.000	1.000
Task 1 Wk						
Task 2 Wk, Cn	.121	.160	.833	.480	.416	.865
Task 3 Wk, Cr	.281	.184	.171	.777	.342	.322
Task 4 Wk, Cn, Cr	.077	.107	.067	.607	.179	.340
Task 5 Wk, Ob	.317	.705	.414	.564	1.000	1.000
Task 6 Wk, Ob, Cn	.181	.125	.439	.277	.785	.262
Task 7 Wk, Ob, Cr	.159	.199	.073	.525	.027*	.474
Task 8 Wk, Ob, Cn, Cr	.144	.016*	.032*	.070	.235	.964
Total	.013*	.017*	.021*	.111	.046*	.730

^{Wk} Walk; ^{Cn} Count; ^{Cr} Coordination; ^{Ob} Obstacle

* $p < .05$

Statistical significance was not found with the ABC between all evaluation moments. Mean values in T1 show a slight decrease in ABC scores, so we hypothesized that those participants who decreased in balance confidence may have done so due to the recognition of balance limitations that was highlighted through the Wii® intervention. Those scores increased again between T1 and T3, with no statistical significance. Fear of falling has been identified in community dwelling elder adults and tends to be higher in women (Peeters et al., 2018). Fear of falling can increase an individual's concern regarding participating in an activity which would lead to activity restriction, resulting in a decrease of self-esteem, confidence, strength and balance, and increasing the

individual's risk of falling (Peeters et al., 2018) This justifies our results. Due to the fact that the sample were the elderly with hardly any educational background, a lack of understanding of the ABC scale may also have led to inaccurate completion of the outcome measures. This can be taken as one of the limitations of this study despite the instrument being clearly explained to the participants.

Due to the complexity of tasks that involves cognitive stimulation as well as motor skills, studies showed that the Wii® could promote integration of motor and cognitive abilities that could contribute to increased independence in daily life compared with other training interventions based on motor stimulation alone (Pompeu et al., 2012). However, our results showed a decrease in IADL scale score in T0-T1 that represents a negative impact of Wii® intervention on independent performance of instrumental activities of daily life, with statistical significance ($P = .032$). However, this was followed by an increase in T2 and T3 moments, similar to the baseline scores. Despite not having justification for these results, they were probably influenced by the bias created with an individual measure evaluation. In fact, some authors have discussed the difficulties in transferring trained skills by video game to real tasks in daily life (Sala et al, 2018).

Researchers have found that older adults were motivated to play the video game and the clients who were most interested and engaged in playing the video game had the greatest gains (Porrás, Siemonsma, Inzelberg, Zeilig, & Plotnik, 2018). This is consistent with our results that shows an increase of health status in Mos-SF-12 mental component in T1 moment ($P = .009$). Studies show that individuals who had experienced the Wii® relate a decrease in anxiety or depression symptoms (Porrás et al, 2018) and had a significant reduced level of depression (Porrás et al, 2018; Maillot, Perrot, & Hartley, 2012). An additional benefit is that the Wii® provides numerous opportunities for social interaction (Chang, Labban, Gapin, & Etnier, 2012) that may have influenced this improvement. This gain in health status is aligned to positive experiences reported by individuals with Wii®Fit, increasing their motivation and health status (Chang et al., 2012). Authors reported that the individual treatment provided by Nintendo Wii® could be advantageous in health status (Porrás et al, 2018).

We also found that practice did result in improved performance on dual-task. Participants showed significant gains in performance on the upper and lower limb motor simultaneous dual-tasks performances. Participants also showed gains in cognitive-motor dual-tasks performances. These improvements show that this inactive population could benefit from the Wii® *exergames*. Studies (Graves et al., 2010) showed that Wii® training generates more enjoyment than sedentary videogame or treadmill exercise in elder adults. Thus, interactive physical-activity videogames

could be an enjoyable alternative to physical activity (Farrance et al, 2016). We speculate that these results are also due to the variability of the tasks and the interactions during the training sessions. This training context required the participant to alternate between tasks that varied in the priority placed on rapidity, accuracy, strategy, cognitive judgment and more global combinations (Maillot et al., 2012). The natural attractiveness of the activities and the motivation of individual feedback are other factors that could have aided in learning dual-tasks performances (Maillot et al., 2012).

Our results are consistent with those of other studies, which show that from this training subjects appear to have learned the ability to distribute their skills among multiple tasks with different processing priorities, and consequently develop the accommodation of their skills to different tasks (Maillot et al., 2012).

In conclusion, training older adults to use Nintendo WiiFit® has shown to improve the mental health component of health status and dual-task protocol, after concluding the intervention. The Nintendo Wii® training is a novel and fun yet productive way for older adults to improve some clinical measures in a low cost manner in a clinical environment supervised by physical therapists.

8. Implications

The results suggest that the development of exercise programs based on this platform can be effective in promoting health gains for the elderly, improving the ability to perform more complex tasks with benefits for their autonomy and reducing health spending. It will be advisable for practitioners and those responsible for organizations providing care to this population to introduce such programs into their guidelines and routines, contributing to public policies for active aging.

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References

- Ackerman, P.L., Kanfer, R., & Calderwood, C. (2010). Use it or lose it? Wii brain exercise practice and reading for domain knowledge. *Psychology and aging*, 25(4), 753-766. <https://doi.org/10.1037/a0019277>
- American College of Sports Medicine (2009). Exercise and Physical Activity for older adults - Position Stand. *Medicine & Science in Sports & Exercise*, 41(7), 1510-1530. <https://doi.org/10.1249/MSS.0b013e3181a0c95c>
- Bamidis, P.D., Vivas, A.B., Styliadis, C., Frantzidis, C., Klados, M., Schlee, W., Siountas, A., & Papageorgiou, S.G. (2014). A review of physical and cognitive interventions in aging. *Neuroscience & Biobehavioral Reviews*, 44, 206-220. <https://doi.org/10.1016/j.neubiorev.2014.03.019>

- Barry, G., Galna, B., & Rochester, L. (2014). The role of exergaming in Parkinson's disease rehabilitation: a systematic review of the evidence. *Journal of neuroengineering and rehabilitation*, 11, 1-10. <https://doi.org/10.1186/1743-0003-11-33>
- Bergamin, M., Gobbo, S., Zanotto, T., Sieverdes, J. C., Alberton, C. L., Zaccaria, M., & Ermolao, A. (2014). Influence of age on postural sway during different dual-task conditions. *Frontiers in Aging Neuroscience*, 6, 271. <https://doi.org/10.3389/fnagi.2014.00271>
- Branco, P. (2010) Validação da Versão Portuguesa da “Activities-specific Balance Confidence Scale”. *Revista da Sociedade Portuguesa de Medicina Física e de Reabilitação*, 19(2), 20-25.
- Chang, Y., Labban, J., Gapin, J., & Etnier, J. (2012). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain Research*, 1453, 87-101. <https://doi.org/10.1016/j.brainres.2012.02.068>
- Cho, G., Hwangbo, G., & Shin, H. (2014). The Effects of Virtual Reality-based Balance Training on Balance of the Elderly. *Journal of Physical Therapy Science*, 26(4), 615-617. <https://doi.org/10.1589/jpts.26.615>
- Farrance, C., Tsofliou, F., & Clark, C. (2016). Adherence to community based group exercise interventions for older people: A mixed-methods systematic review. *Preventive Medicine*, 87, 155-166. <https://doi.org/10.1016/j.ypmed.2016.02.037>
- Folstein, M., Robins, L., & Helzer, J. (1983). The mini-mental state examination. *Archives of General Psychiatry*, 40(7), 812. <https://doi.org/10.1001/archpsyc.1983.01790060110016>
- Garcia, J., Navarro, K., Schoene, D., Smith, S., & Pisan, Y. (2012). Exergames for the elderly: towards an embedded Kinect-based clinical test of falls risk. *Studies in health technology and informatics*, 178, 51-57.
- Graf, C. (2008). The Lawton Instrumental Activities of Daily Living Scale. *The American Journal of Nursing*, 108(4), 52-62. <https://doi.org/10.1097/01.NAJ.0000314810.46029.74>
- Graves, L., Ridgers, N., Williams, K., Stratton, G., Atkinson, G., & Cable, N. (2010). The physiological cost and enjoyment of Wii Fit in adolescents, young adults, and older adults. *Journal of Physical Activity and Health*, 7(3), 393-401. <https://doi.org/10.1123/jpah.7.3.393>
- Halvarsson, A., Dohrn, I., & Stahle, A. (2015). Taking balance training for older adults one step further: the rationale for and a description of a proven balance training programme. *Clinical Rehabilitation*, 29(5), 417-425. <https://doi.org/10.1177/0269215514546770>
- Jehu, A., Paquet, N., & Lajoie, Y. (2017). Balance and Mobility Training With or Without Simultaneous Cognitive Training Reduces Attention Demand But Does Not Improve Obstacle Clearance in Older Adults. *Motor Control*, 22(3), 275-294. <https://doi.org/10.1123/mc.2017-0024>
- Laver, K., George, S., Thomas, S., Deutsch, J., & Crotty, M. (2012). Cochrane review: virtual reality for stroke rehabilitation. *European journal of physical and rehabilitation medicine*, 48(3), 523-530.
- Maillot, P., Perrot, A., & Hartley, A. (2012). Effects of interactive physical-activity video-game training on physical and cognitive function in older adults. *Psychology and aging*, 27(3), 589-600. <https://doi.org/10.1037/a0026268>
- Morgado, J., Rocha, C., Maruta, C., Guerreiro, M., & Martins, I. (2009). New normative values of Mini-Mental State Examination. *Sinapse*, 9(2), 10-16.
- Peeters, G., Leahy, S., Kennely, S., & Kenny, R. (2018). Is Fear of Falling Associated With Decline in Global Cognitive Functioning in Older Adults: Findings From the Irish Longitudinal Study on Ageing. *Journal of the American Medical Directors Association*, 19(3), 248-254. <https://doi.org/10.1016/j.jamda.2017.09.012>
- Pompeu, J., Mendes, F., Silva, K., Lobo, A., Oliveira, T., Zomignani, A., & Piemonte, M. (2012). Effect of Nintendo Wii™-based motor and cognitive training on activities of daily living in patients with Parkinson's disease: A randomised clinical trial. *Physiotherapy*, 98(3), 196-204. <https://doi.org/10.1016/j.physio.2012.06.004>
- Porras, D., Siemonsma, P., Inzelberg, R., Zeilig, G., & Plotnik, M. (2018). Advantages of virtual reality in the rehabilitation of balance and gait. *Neurology*, 90(22), 1017-1025. <https://doi.org/10.1212/WNL.0000000000005603>

- Powell, L., & Myers, A. (1995). The Activities-specific Balance Confidence (ABC) Scale. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 50A (1), M28-M34. <https://doi.org/10.1093/gerona/50A.1.M28>
- Purath, J., Keller, C., McPherson, S., & Ainsworth, B. (2013). A randomized controlled trial of an office-based physical activity and physical fitness intervention for older adults. *Geriatric nursing*, 34(3), 204-211. <https://doi.org/10.1016/j.gerinurse.2013.02.012>
- Reed-Jones, R., Dorgo, S., Hitchings, M., & Bader, J. (2012). WiiFit Plus balance test scores for the assessment of balance and mobility in older adults. *Gait & posture*, 36(3), 430-433. <https://doi.org/10.1016/j.gaitpost.2012.03.027>
- Rendon, A., Lohman, E., Thorpe, D., Johnson, E., Medina, E., & Bradley, B. (2012). The effect of virtual reality gaming on dynamic balance in older adults. *Age and ageing*, 41(4), 549-552. <https://doi.org/10.1093/ageing/afs053>
- Roberts, C., Phillips, L., Cooper, C., Gray, S., & Allan, J. (2017). Effect of Different Types of Physical Activity on Activities of Daily Living in Older Adults: Systematic Review and Meta-Analysis. *Journal of Aging and Physical Activity*, 25(4), 653-670. <https://doi.org/10.1123/japa.2016-0201>
- Sala, G., Tatlidil, S., & Gobet, F. (2018). Video game training does not enhance cognitive ability: A comprehensive meta-analytic investigation. *Psychological Bulletin*, 144(2), 111-139. <https://doi.org/10.1037/bul0000139>
- Spirduso, W., Francis, K., & MacRae, P. (2005). *Physical dimensions of aging*. (2nd ed.). Champaign, IL: Human Kinetics.
- Tore, P., & Raiola, G. (2012). Exergames and motor skills learning: a brief summary. *International Research Journal of Applied and Basic Sciences*, 3(6), 1161-1164.
- van Diest, M., Lamoth, C., Stegenga, J., Verkerke, G., & Postema, K. (2013). Exergaming for balance training of elderly: state of the art and future developments. *Journal of neuroengineering and rehabilitation*, 10, 101. <https://doi.org/10.1186/1743-0003-10-101>
- Walshe, E., Patterson, M., Commings, S., & Roche, R. (2015). Dual-task and electrophysiological markers of executive cognitive processing in older adult gait and fall-risk. *Front. Hum. Neurosci.* 9:200. <https://doi.org/10.3389/fnhum.2015.00200>
- Ware, J., & Sherbourne, C. (1992). The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care*, 30(6), 473-483. <https://doi.org/10.1097/00005650-199206000-00002>
- World Health Organization. (2011). Global health and ageing. U.S. Department of Health and Human Services, US National Institute of Aging, 32.