Original Article

The effect of balance therapy on postural stability in a group of seniors using active video games (Nintendo wii)

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Abstract:

Impaired postural stability increases the risk of falls. Therefore, the aim of this study was to analyse the lasting effects of a training intervention using a Nintendo Wii system on impaired postural stability in an elderly population. Thirty-two elderly subjects (24 females and 4 males) from two independent living communities were divided into Wii Fit (n = 15, 9 therapy sessions using Wii Fit balance board) and control (n = 13) groups. All participants performed three different stances on force plates, which are considered the gold standard for measuring balance performance. Each stance was measured three times in the following sequence: a natural bipedal stance with eyes open, a bipedal stance with a narrow base, and a natural bipedal stance with eyes closed. One-way analysis of variance (ANOVA) and LSD Fisher's post hoc tests were used with the level of significance set at 5%. Effect size was determined using η^2 . The results showed a significant difference in the centre of pressure velocity in the anterior-posterior direction between the baseline and post-treatment measurements (post-intervention and follow up) for all measured conditions in Wii Fit Group. The control group did not show any significant differences between measurements. The results of this study suggest that using the Nintendo Wii is an effective physical activity for improving balance in the elderly and that the effects of balance therapy on postural stability persist for several weeks after intervention.

Key words: static balance, force plate, centre of pressure, elderly, physical activity

Introduction

In the US, two and a half million older people are treated in emergency departments for fall-related injuries, and over 700,000 seniors are hospitalized each year. Not only is quality of life lower after these incidents, but these falls can also lead to the death (Centers for disease control and prevention, 2015). Each year, one out of five falls causes a serious injury. Most injuries are to the head (47%), upper limbs (28%) and lower limbs (26%), (Majkusová & Jarošová, 2014).

Impaired coordination, balance, and gait are associated with a higher risk of falling in the elderly (Bainbridge, Bevans, Keeley, & Oriel, 2011; Melzer, Benjuya, & Kaplanski, 2004). Furthermore, risk of falling is higher in those with worsened health or psychological conditions such as sensory deficits (mainly impaired vision), the use of supportive equipment or drugs (antihypertensive, psychotropic medications), fear of falls, fainting, and sleep disorders. Floor material can also negatively influence balance.

With increased age, muscles lose both quality and quantity, and bone mineral density changes (Pereira, Vogelaere, & Baptista, 2008). Physiological aspects of ageing include decreased total muscle capacity, higher adiposity in women, lower muscle density, less muscle strength, lower muscle power, and decreased muscle volume (Brady, & Straight, 2014; Degens, Erskine, & Morse, 2009). In turn, decreased muscle capacity negatively influences physical functions (Brady, & Straight, 2014). For example, 37% of seniors between the ages of 65 and 74 and 42% of seniors older than 75 were injured due to impaired physical function (Kolář, 2013).

Good balance requires upright posture, which involves three body systems: the sensory (proprioception, vision, and the vestibular system), control (the brain and spinal cord) and executive function systems (the musculoskeletal system and soft tissues surrounding the impacted bone) (Bainbridge, et al., 2011; Pereira, et al., 2008). The capacity of all three areas can be increased by physical activity.

Physical activity has been shown to decrease the risk of falling due to its positive impact on balance and strength (Daly, et al., 2008; Keogh, Justin, W., Power, Wooller, Lucas, & Whatman, 2014; Lee, Biggan, Taylor, & Ray, 2014; Lehnert, M., Chmelík, F., Cuberek, R., & Svobodová, V., 2014). Currently, there are various possibilities for conducting physical activities in elderly populations, such as strength training with machines, functional strength training (Lohne-Seiler, Torstveit, & Anderssen, 2013), joint-mobility training, muscle coordination training (Santana-Sosa, Barriopedro, López-Mojares, Pérez, & Lucia, 2008) or various combinations of different approaches. It is believed, though not completely understood, that high-intensity

training and high-velocity strength training in elderly populations lead to an increase in the number and diameter of motor neurons. Additionally, both directions of nerve impulse transmission are faster after this type of training. Physiological adaptations, such as an increase in the cross-sectional area of muscles after strength training, are better documented than neuromuscular adaptation (Lohne-Seiler, et al., 2013).

Due to technological advances, physical activity via the Nintendo Wii gaming system (USA) can be executed. The Nintendo Wii is safe and has no side effects. Moreover, it has the benefit of producing higher motivation in clients because they are playing a game and receive immediate feedback from the screen (Bower, Clark, McGinley, Martin, & Miller, 2014; Keogh, Justin, W., et al., 2014). Keog et al. (2014) described the positive effect of the Wii on functional ability and improvements in upper limb strength in elderly subjects after eight weeks of intervention. Additionally, a study on patients recovering from stroke (Bower, et al., 2014) showed a positive effect on upper limb strength development after only two to four weeks of intervention. Toulotte, Toursel and Olivier (2012) showed that twenty weeks of Nintendo Wii balance training in a healthy elderly population improved results of clinical tests (Tinetti and Unipedal tests) and also improved stability during a Wii fit test, which was measured as the centre of pressure (COP) movement and distribution of pressure between the right and left foot - calculated as the difference between the percentage of position of the COP on each foot. However, that study did not assess specific directions of COP, such as the mediolateral or anteroposterior directions, that provide more detailed information about coordination, balance and gait. Similar results were reported by Lee et al. (2014) after a ten-week training intervention using the Nintendo Wii in an elderly population. Therapy results in an increase in velocity, stride length, cadence, and swing time and a decrease in double support time. There was no control group in this study.

To our knowledge, no study has yet examined the lasting effects of a Nintendo Wii training intervention in an elderly population. Therefore, the aim of our study was to assess the long-term effects of a training intervention using the Nintendo Wii in an elderly population.

Furthermore, because of the reasons mentioned above, we compared elderly subjects using Nintendo Wii balance therapy to improve balance to a control group and observed the standard deviation of COP in specific directions. Moreover, we observed velocity characteristics of COP in specific directions that are considered to be more relevant markers for balance (Raymakers, Samson, & Verhaar, 2005).

Materials and Methods

Participants

The screened population consisted of elderly participants living in two different residential communities. Thirty-two volunteers participated in this study. The Wii Fit Group consisted of 15 participants (14 females, 1 male, 81 ± 8 years, 72 ± 23 kg, 159 ± 12 cm), and the control group consisted of 13 participants (10 females and 3 males, 84 ± 11 years, 74 ± 22 kg, 163 ± 12 cm) who received no physical activity intervention. Each volunteer signed an informed consent document before participating in the study. The inclusion criteria were a minimum of 65 years of age and a decreased score in least two of three clinical balance tests: Time Up and Go – cut-off 15 s (Nordin, Lindelöf, Rosendahl, Jensen, & Lundin – Olsson, 2008), Functional reach test – 18.5 cm (Thomas, & Lane, 2005), and the Berg balance scale – 21-40 points considered “medium fall risk”, under 20 points considered “high fall risk” (Berg, Wood-Dauphinee, Williams, & Gayton, 1989). The exclusion criteria were vestibular problems, stroke in the last two years and acute problems such as current fever, immobilization or inflammation. Two participants were excluded after examination, and two subjects left the study due to hospitalization. The study was reviewed and approved by the local university’s ethics committee.

Measurement

To determine the basic biomechanical parameters of postural stability in participants, two Kistler force platforms (type 9286AA, Kistler Instrument AG, Winterthur, Switzerland) with a frequency of 200 Hz were used.

Participants were asked to stand with one lower limb on each force platform and hold this position for 30 seconds with the hands positioned alongside the body to minimize body sways. Stability was tested in three different stances, each of which was tested three times in the following sequence: a natural bipedal stance with eyes open, a bipedal stance with a narrow base, and a natural bipedal stance with eyes closed. Patients were tested without any supportive devices and wore their regular shoes during testing.

Data collection and analysis

The stability assessment was measured as the standard deviation in COP displacement in both the mediolateral (SD_{ML} , mm) and anteroposterior directions (SD_{AP} , mm). The mean COP velocity in the mediolateral (v_{ML} , mm/s) and anteroposterior directions (v_{AP} , mm/s) and the total velocity (v , mm/s) were measured.

Statistical analyses were conducted using STATISTICA 10 (Stat-Soft, Inc., Tulsa, USA). One-way repeated-measures ANOVA and LSD Fisher’s post hoc test were used to detect differences between groups.

Furthermore, for observed significant differences, the effect size was determined using η^2 with small, medium and large effects defined as 0.01, 0.059 and 0.138, respectively. Statistical significance was defined as $\alpha = 0.05$. The control group and Wii Fit group were measured before and after the intervention. Additionally, a measurement was conducted in the Wii Fit Group one month after therapy to assess lasting effects.

Intervention of Wii Fit Group

Wii Fit therapy was carried out using the Nintendo standardized video games (Wii Fit Plus, Japanese). Each participant completed a total of 9 therapeutic sessions occurring two to three times per week over four weeks. Each therapeutic session lasted 20 minutes, during which the three selected video games (penguin slide, table tilt and balance bubble) were played for 5 minutes each. The remaining 5 minutes were used for rest, with subjects resting for 1.5 minutes after each game. Games were chosen in order to allow body movement in both the mediolateral and anteroposterior directions. The same set of Nintendo Wii games has been applied in several previous studies focused on balance (Bainbridge, et al., 2011; Lee, et al., 2014; Nicholson, McKean, Lowe, Fawcett, & Burkett, 2015). During balance training, we supervised the subjects to prevent actual falls or the fear of falls and helped subjects if it became necessary. Moreover, subjects had a chair in front of them to help them feel safe and confident.

Results

Comparisons of the three measurements of postural stability at baseline, post-intervention, and at follow up in the Wii Fit Group are shown in Table 1.

Table 1. Changes in the centre of pressure parameters in the Wii Fit Group

Condition	Variable	Baseline		Post-Intervention		Follow up		Significance level p		
		M	SD	M	SD	M	SD	1 x 2	1 x 3	2 x 3
Open eyes	SD _{ML} (mm)	4.3	4.3	3.3	1.8	2.9	1.5	0.321	0.151	0.638
	SD _{AP} (mm)	6.4	2.2	5.9	1.4	5.5	0.9	0.342	0.118	0.517
	v _{ML} (mm/s)	8.1	7.5	5.8	2.3	5.2	1.5	0.187	0.098	0.715
	v _{AP} (mm/s)	14.6	3.9	12.6	3.3	12.8	3.9	0.045[#]	0.069	0.829
	v (mm/s)	18.7	7.8	15.0	4.4	14.8	4.3	0.059	0.044[#]	0.886
Narrow base	SD _{ML} (mm)	6.7	2.0	5.7	1.6	5.3	1.9	0.060	0.008[#]	0.346
	SD _{AP} (mm)	6.4	1.1	6.4	1.3	6.1	1.1	0.935	0.885	0.950
	v _{ML} (mm/s)	15.8	6.3	14.1	8.2	11.8	3.6	0.617	0.077	0.191
	v _{AP} (mm/s)	18.6	5.2	16.1	6.4	14.7	3.7	0.161	0.037*	0.443
	v (mm/s)	27.2	8.4	23.8	11.0	21.0	5.3	0.331	0.044*	0.261
Closed eyes	SD _{ML} (mm)	3.1	1.6	2.9	1.7	3.4	1.9	0.551	0.572	0.251
	SD _{AP} (mm)	5.8	1.2	5.9	1.6	5.8	1.2	0.962	0.896	0.934
	v _{ML} (mm/s)	6.3	2.3	6.1	2.3	6.1	2.0	0.742	0.348	0.538
	v _{AP} (mm/s)	16.8	4.6	14.9	4.5	14.7	4.3	0.028^{&}	0.020^{&}	0.866
	v (mm/s)	19.1	5.3	17.3	5.4	17.0	4.8	0.049^{&}	0.019^{&}	0.664

Legend: M – mean, SD – standard deviation, SD_{ML} – standard deviation of COP movement in the mediolateral direction, SD_{AP} – standard deviation of COP movement in the anteroposterior direction, v_{ML} – average velocity of the COP in the mediolateral direction, v_{AP} – average velocity of the COP in the anteroposterior direction, v – total velocity, significant values of $p < 0.05$ are in bold type, 1 x 2 – comparison of the first and second measurements, 1 x 3 – comparison of the first and third measurements, 2 x 3 – comparison of the second and third measurements, * – large effect, [#] – medium effect, [&] – small effect.

There were significant differences between the Wii Fit and control group at baseline. Comparisons of the baseline and post-intervention measurements in the control group are presented in Table 2.

Discussion and conclusion

This study evaluated postural balance using postural sways (COP displacement SD) and COP velocity in specific directions. The most beneficial way to reduce the risk of injuries in elderly populations is prevention, such as an adequate amount of physical activity (Lee, et al., 2014). Muscle-quality loss and worsened body posture and coordination due to ageing can be partially alleviated via physical activity (Pereira, et al., 2008). Research has suggested that exercises on the Nintendo Wii could be one method to improve balance in the elderly.

In the Wii Fit group, significant differences were found between baseline and follow-up for v_{AP} and v measurements in the natural bipedal stance with eyes open (medium effect) and with eyes closed (small effect) and in the bipedal stance with a narrow base (large effect). Additionally, in the narrow base stance, there was a

significant difference in SD_{ML} (medium effect). No significant differences were found in the control group. Table 1 shows the improvements in the parameter means of v_{AP} in the natural bipedal stance with eyes open and in the SD_{ML} direction in the natural bipedal stance with eyes closed. In the case of v_{AP} in the natural bipedal stance, there is a significant difference between the first and second measurements; thus since the mean values of second and third measurements are similar (12.6 ± 3.3 and 12.8 ± 3.9 , respectively), we can assume the subjects had better postural stability at follow-up despite the non-significance of this result.

We have found significant differences in v_{AP} after therapy that may be attributable to the type of games selected. Two of the three games (balance bubble, table tilt) focused primarily on the AP direction but also required maintaining balance in the ML direction. Nicholson, McKean, Lowe, Fawcett and Burkett (2015) have also shown improvements in the ML direction that were attributed to similar games (seven of nine were focused on the ML direction). This phenomenon can be associated with specifically targeted strength training programmes leading to corresponding specific adaptations (Kraemer & Ratamess, 2004).

Although v improved after balance therapy in all three stances, v_{ML} showed no significant improvements. However, we did observe a trend showing progress in this parameter with a medium effect size. Because deficits in ML stability are associated with increased risk of falling in the elderly (Hilliard, et al., 2008), we can assume this trend could positively affect the overall stability and balance in this population.

Postural stability significantly improved in other studies with a duration of 10 (Lee, et al., 2014) or 20 weeks (Toulotte, Toursel, & Olivier, 2012). However, in the latter, the authors used a different set of tests (Unipedal test, Static and Dynamic Tinetti tests, and the position of the centre of pressure (Wii Fit) test) that provided only general assessments of balance that cannot be considered as direct measurements of velocity on the platform. Contrastingly, in a study by Bainbridge et al. (2011), the authors concluded that 6 weeks of intervention did not result in any significant improvements, likely due to the small sample size of the study. The previously mentioned studies focused on the effects of longer interventions in elderly populations. However, a study by Kliem and Wiemeyer (2010) used similar intervention duration as our study. This study compared two intervention programmes in elderly subjects – a programme using the Nintendo Wii and a programme using specific training devices for balance improvement. The authors concluded that there were no differences in the training effects of the two programmes. However, they did not assess any lasting effects that could show further details about these interventions.

To our knowledge, our study is the first to demonstrate a lasting effect of a Nintendo Wii-based training programme in an elderly population. The persistent effect after the nine 20-minute sessions promises to minimize the required time demands of physical activity, which is an advantage in the very sedentary and hectic lifestyle of today (Owen, Healy, Matthews, & Dunstan, 2010). If verified by future studies, we presume that elderly patients could participate in training programmes consisting of alternating sessions of exercise and rest. Recent studies have shown that 4-week duration is sufficient for neural adaptations induced by strength training (Del Balso & Cafarelli, 2007; Folland & Williams, 2007).

The main limitations of the present study are the small sample size and the non-homogeneity of the included subjects. Another limitation of the study is the differences in the two study groups due to inherent differences between the two residential communities. These communities were chosen due to existing relationships. Additionally, frequent transport of our measuring devices was not possible, and residential communities have little space for interventions. However, all analyses of baseline and post-intervention data were performed independently for each community.

In conclusion, the results of this study suggest that the Nintendo Wii exercise is an effective physical activity to improve balance in elderly populations. The findings also showed that the effect of balance therapy on postural stability persists for several weeks after the intervention.

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References

- Bainbridge, E., Bevans, S., Keeley, B., & Oriel, K. (2011). The effects of the Nintendo Wii Fit on community-dwelling older adults with perceived balance deficits: A pilot study. *Physical & Occupational Therapy in Geriatrics*, 29(2), 126–135.
- Bower, K.J., Clark, R.A., McGinley, J.L., Martin, C.L., & Miller, K.J. (2014). Clinical feasibility of the Nintendo Wii™ for balance training post-stroke: a phase II randomized controlled trial in an inpatient setting. *Clinical Rehabilitation*, 28(9), 912–923.
- Brady, A.O., & Straight, C.R. (2014). Muscle capacity and physical function in older women: What are the impacts of resistance training? *Journal of Sport and Health Science*, 3(3), 179–188.
- Centers for diseases control and prevention. (2015). *Important facts about falls*. Retrieved January 18, 2016 from the World Wide Web: <http://www.cdc.gov/homeandrecreationalsafety/falls/adultfalls.html>

- Daly, R.M., Ahlborg, H.G., Ringsberg, K., Gardsell, P., Sernbo, I., & Karlsson, M.K. (2008). Association between changes in habitual physical activity and changes in bone density, muscle strength, and functional performance in elderly men and women. *Journal of the American Geriatrics Society*, 56(12), 2252–2260.
- Degens, H., Erskine, R.M., & Morse, C.I. (2009). Disproportionate changes in skeletal muscle strength and size with resistance training and ageing. *Journal of Musculoskeletal Neuronal Interactions*, 9(3), 123–129.
- Del Balso, C., & Cafarelli, E. (2007). Adaptations in the activation of human skeletal muscle induced by short-term isometric resistance training. *Journal of Applied Physiology*, 103(1), 402–411.
- Folland, J.P., & Williams, A.G. (2007). The adaptations to strength training. *Sports Medicine*, 37(2), 145–168.
- Hilliard, M.J., Martinez, K.M., Janssen, I., Edwards, B., Mille, M.L., Zhang, Y., & Rogers, M.W. (2008). Lateral balance factors predict future falls in community-living older adults. *Archives of Physical Medicine and Rehabilitation*, 89(9), 1708–1713.
- Keogh, J.W.L., Power, N., Wooller, L., Lucas, P., & Whatman, C. (2014). Physical and psychosocial function in residential aged-care elders: effect of Nintendo Wii sports games. *Journal of Aging and Physical Activity Journal of Aging and Physical Activity*, 22, 235–244.
- Kolář, P. (2013). *Clinical rehabilitation*. Rehabilitation Prague School.
- Kovacikova, Z., Svoboda, Z., Neumannova, K., Bizovska, L., Cuberek, R., & Janura, M. (2014). Assessment of postural stability in overweight and obese middle-aged women. *Acta Universitatis Palackianae Olomucensis, Gymnica*, 44(3), 149–153.
- Kozáková, D., Svoboda, Z., Janura, M., Elfmark, M., & Nedvěďová, I. (2009). Assessment of postural stability in patients with a transtibial amputation with various times of prosthesis use. *Acta Universitatis Palackianae Olomucensis, Gymnica*, 39(3), 51–59.
- Kraemer, W.J., & Ratamess, N.A. (2004). Fundamentals of resistance training: progression and exercise prescription. *Medicine and Science in Sports and Exercise*, 36(4), 674–688.
- Lee, A., Biggan, J.R., Taylor, W., & Ray, C. (2014). The effects of a Nintendo Wii exercise intervention on gait in older adults. *Activities, Adaptation & Aging*, 38(1), 53–69.
- Lehnert, M., Chmelík, F., Cuberek, R., & Svobodová, V. (2014). Strength asymmetry of the knee extensors and physical activity in middle-aged women. *Acta Gymnica*, 44(3), 141–147.
- Lohne-Seiler, H., Torstveit, M. K., & Anderssen, S. A. (2013). Traditional versus functional strength training: Effects on muscle strength and power in the elderly. *Journal of Aging and Physical Activity*, 21(1), 51–70.
- Majkusová, K., & Jarošová, D. (2014). Falls risk factors in an acute-care setting: a retrospective study. *Central European Journal of Nursing and Midwifery*, 5(2), 47–53.
- Maribo, T., Stengaard-Pedersen, K., Jensen, L. D., Andersen, N. T., & Schiøttz-Christensen, B. (2011). Postural balance in low back pain patients: Intra-session reliability of center of pressure on a portable force platform and of the one leg stand test. *Gait and Posture*, 34(2), 213–217.
- Melzer, I., Benjuya, N., & Kaplanski, J. (2004). Postural stability in the elderly: A comparison between fallers and non-fallers. *Age and Ageing*, 33(6), 602–607.
- Nicholson, V.P., McKean, M., Lowe, J., Fawcett, C., & Burkett, B. (2015). Six weeks of unsupervised Nintendo Wii Fit gaming is effective at improving balance in independent older adults. *Journal of Aging and Physical Activity*, 23(1), 153–158.
- Nordin, E., Lindelöf, N., Rosendahl, E., Jensen, J., & Lundin – Olsson, L. (2008). Prognostic validity of the Timed Up – and – Go test, a modified Get – Up – and – Go test, staff's global judgement and fall history in evaluating fall risk in residential care facilities. *Age and Ageing*, 37(4), 442–448.
- Owen, N., Healy, G. N., Matthews, C. E., & Dunstan, D. W. (2010). Too much sitting: the population-health science of sedentary behavior. *Exercise and Sport Sciences Reviews*, 38(3), 105–113. <http://doi.org/10.1097/JES.0b013e3181e373a2>.Too
- Pereira, C.L.N., Vogelaere, P., & Baptista, F. (2008). Role of physical activity in the prevention of falls and their consequences in the elderly. *European Review of Aging and Physical Activity*, 5(1), 51–58.
- Raymakers, J.A., Samson, M.M., & Verhaar, H.J.J. (2005). The assessment of body sway and the choice of the stability parameter(s). *Gait and Posture*, 21(1), 48–58.
- Santana-Sosa, E., Barriopedro, M.I., López-Mojares, L.M., Pérez, M., & Lucia, A. (2008). Exercise training is beneficial for Alzheimer's patients. *International Journal of Sports Medicine*, 29(10), 845–850.
- Thomas, J. I., & Lane, J. V. (2005). „A pilot study to explore predictive validity of 4 measures of falls risk in frail elderly patients.“ *Archives of Physical Medicine and Rehabilitation*, 86(8), 1636–1640.
- Toulotte, C., Toursel, C., & Olivier, N. (2012). Wii Fit training vs. Adapted Physical Activities: which one is the most appropriate to improve the balance of independent senior subjects? A randomized controlled study. *Clinical Rehabilitation*, 26(9), 827–835.