

Original Article

Kinematic effect of Nintendo Wii™ sports program exercise on obstacle gait in elderly women with falling risk

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Abstract. [Purpose] This study evaluated the changes in balance ability and obstacle gait after lumbar stabilization exercise and Nintendo Wii™ Sports in elderly at risk for falls. [Subjects and Methods] Twenty-four elderly women with at risk for falls were randomly divided into the control, lumbar stabilization exercise, and Nintendo Wii Sports groups. Static balance was measured by the Berg Balance Scale and functional reach test, dynamic balance by the timed up-and-go test, and obstacle negotiation function by crossing velocity and maximum vertical heel clearance. [Results] Both the lumbar stabilization exercise and Nintendo Wii Sports groups showed significant improvements in obstacle negotiation function after the exercise compared to the control group. Berg Balance Scale and functional reach test scores were greater in the lumbar stabilization exercise group, while the timed up-and-go test time was significantly better in the Nintendo Wii Sports groups. [Conclusion] Lumbar stabilization exercises and Nintendo Wii Sports improve falling related balance and obstacle negotiation function in elderly women at risk for falls.

Key words: Elderly women, Falls, Nintendo Wii Sports

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INTRODUCTION

Approximately 28–35% and 32–42% of people more than 60 and 70 years old, respectively, experience falls every year worldwide^{1, 2)}; 30% of those experiencing falls require medical attention to treat resultant abrasions and sprains, and approximately 10% require hospitalization for fractures³⁾.

For elderly women in particular, aging-related organ degeneration is enhanced by a significant reduction of bone mass due to menopause; therefore, they are more vulnerable to serious fractures caused by falls, which can lead to secondary illnesses⁴⁾.

As people age, their abilities to maintain balance and ambulate degrade which increases falling risk during walking⁵⁾. In particular, falling caused by obstacle such as thresholds, bath sills, and speed bumps in parking lots occur frequently^{6, 7)}.

Among various intervention methods for fall prevention and obstacle negotiation, exercise improves muscular

strength, flexibility, and balance, aiding the maintenance of body balance; therefore, it is widely used in programs to prevent falls⁸⁾.

However, existing exercise methods to prevent falls largely depend on physical therapists. Therefore, patients tend to become bored performing passive exercises with simple repetitions; together with cost, time, and location constraints this results in decreased desire for treatment⁹⁾.

Therefore, an in-home exercise method that is interesting with fewer time and spatial limitations, and enables continuous exercise is desirable.

Nintendo Wii™ Sports is a virtual reality-based exercise game. It is relatively inexpensive and small enabling exercise in a small space. In addition, it offers immediate visual and audio feedback from exercise, generating interest and improving the effect of motor learning¹⁰⁾. Previous studies using Nintendo Wii Sports involved basic balance assessment for patients and elderly^{11–13)}, but few have focused on the negotiation of obstacles that frequently cause falls.

Hence, this study evaluated the changes in balance ability and obstacle gait after lumbar stabilization exercise and Nintendo Wii Sports in elderly at risk for falls. Furthermore, we whether Nintendo Wii Sports are appropriate and effective as self-help exercises to prevent falls when performed at home by elderly women at risk of falls.

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Table 1. General characteristics of the participants (N=24)

	Control (n = 8)	LSE (n = 8)	NWS (n = 8)	
Age (years)	73.6 ± 2.4	74.3 ± 3.5	74.3 ± 2.1	*
Height (cm)	151.6 ± 5.4	152.5 ± 4.4	152.9 ± 4.5	*
Weight (kg)	55.3 ± 6.2	54.9 ± 9.6	55.3 ± 7.6	*

Mean ± SD. LSE: lumbar stabilization exercise; NWS: Nintendo Wii Sports. *t test (p < 0.05)

SUBJECTS AND METHODS

The study participants were selected by convenience sampling from 3 senior citizen centers; 24 elderly women above the age of 65 (Table 1) who scored between 19 and 24 points on the Tinetti Performance Oriented Mobility Assessment (POMA) without neurological or orthopedic disorders, experience participating in regular fall prevention programs (i.e., balance exercises) at least twice per week within the last 6 months, or a history of falls were selected¹⁴. The purpose and methods of this study were explained to the participants, who signed an informed consent that outlined all details of the study protocol, which was approved by the Ethics Committee of Kangwon National University (No. 2014-05-002-001).

The participants were randomly divided into the control, lumbar stabilization exercise (LSE), and Nintendo Wii Sports (NWS) groups. Participants in the LSE and NWS groups, but not the control group performed an exercise program. Participants performed exercises twice weekly for 8 weeks. Each session lasted 30 minutes. LSE included 7 positions based on the back bridge, hands and knees, and side bridge as follows¹⁵: (1) standard back bridge, (2) back bridge with alternate leg straight, (3) back bridge with one leg, (4) standard hands and knees, (5) hands and knees with alternate arm straight forward, (6) hands and knees with alternate leg straight backward, and (7) side bridge. LSE group participants were instructed to maintain each position for 15 seconds for 3 sets. The Nintendo Wii Sports program including the wakeboard, Frisbee dog, jet ski, and canoe games was used for the NWS group. NWS group participants controlled a virtual character on the screen by swinging, rowing, or tilting remote controllers with motion sensors. Participants chose their 3 favorite games and took a 2-minute break every 10 minutes.

Before and after 8 weeks of intervention, the participants of each group were evaluated for static balance ability, dynamic balance ability, and obstacle gait by using the following instruments: Berg Balance Scale (BBS) and functional reach test (FRT) for static balance ability; the timed up-and-go (TUG) test for dynamic balance ability; and crossing velocity (CV) and maximum vertical heel clearance (MVHC) for obstacle gait. CV was calculated by dividing the horizontal distance from where the leading limb takes off the ground to where the heel of the leading limb touches the ground after obstacle negotiation by time spent. MVHC was calculated by measuring the vertical distance between the height of an obstacle and the ball of the leading limb before obstacle negotiation¹⁶; the obstacle's dimensions were 60 × 10 × 15.2 cm (width × length × height). The participants

were instructed to start walking 5 m behind the obstacle, negotiate the obstacle, and then walk 3 more meters. Obstacle gait-related factors were recorded by a camcorder and stored on a computer. CV and MVHC were calculated using Dartfish software (Dartfish, Switzerland).

The data were analyzed by SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). The independent samples t-test was used to compare the two groups at the baseline. Two-way repeated-measures ANOVA was used to compare the differences among groups, and post hoc analysis was conducted using the Tukey least significant difference test. The significance level was set at p < 0.05.

RESULTS

The general characteristics of the participants are shown in Table 1; there were no significant differences among groups with respect to age, height, or weight (p > 0.05).

Repeated measure ANOVA to analyze changes in the BBS, the FRT, the TUG, CV, and MVHC according to the measurement periods showed that there was a statistically significant difference in the interaction between time and the groups and that the changes in the BBS, the FRT, the TUG, CV, and MVHC according to time differed (p < 0.001) (Table 2). The LSE and NWS groups exhibited significantly greater increases in mean BBS score, FRT score, and CV than the control group and significantly greater reductions in mean TUG test time and the MVHC.

DISCUSSION

The findings of this study suggest lumbar stabilization exercise and Nintendo Wii Sports might be useful fall prevention interventions for improving fall-related balance and obstacle negotiation function in elderly women at risk of falls.

When elderly people perform gait to overcome an obstacle, their trailing limbs is far more behind the obstacle than that of normal adults; meanwhile, their leading limb makes the distance between the peak of the obstacle and their foot too long, thus reducing the crossing velocity and increasing MVHC^{7, 17}. Elderly people place their leading limb too high when negotiating the obstacle, which elevates their center of mass and consequently reduces balance¹⁸. Thus, CV and MVHC are important factors in their obstacle gait and basic balance ability, which are required to negotiate obstacles in a natural way and thus prevent falls.

The Nintendo Wii Sports program involves exercise games and offers various visual and audio feedback. It can be developed into a program that both spurs interest and

Table 2. Changes in physical and psychological functions

		Control (n = 8)	LSE (n = 8)	NWS (n = 8)	Post hoc
BBS (score)	Pre-intervention	39.8 ± 1.8	39.3 ± 1.5	39.1 ± 1.4	a < b, c
	Post-intervention	38.4 ± 1.9	43.8 ± 1.3	41.0 ± 2.2***	b > c
FRT (cm)	Pre-intervention	18.7 ± 1.0	18.7 ± 1.8	18.8 ± 2.4	a < b, c
	Post-intervention	18.6 ± 1.0	22.3 ± 2.0	21.0 ± 2.2***	b > c
TUG (s)	Pre-intervention	12.0 ± 1.2	12.1 ± 1.4	12.1 ± 2.3	a > b, c
	Post-intervention	12.0 ± 1.6	10.5 ± 1.2	9.4 ± 2.3***	b > c
CV (m/s)	Pre-intervention	1.4 ± 0.1	1.4 ± 0.1	1.4 ± 0.1	
	Post-intervention	1.4 ± 0.1	1.5 ± 0.1	1.5 ± 0.1***	a < b, c
MVHC (cm)	Pre-intervention	5.9 ± 1.5	6.0 ± 1.3	5.9 ± 0.7	
	Post-intervention	6.0 ± 1.6	5.0 ± 1.3	4.9 ± 0.4***	a > b, c

Mean ± SD. LSE: lumbar stabilization exercise; NWS: Nintendo Wii Sports; BBS: Berg Balance Scale; FRT: functional reach test; TUG: timed up-and-go test; CV: crossing velocity; MVHC: maximum vertical heel clearance. ***p < 0.001.

improve motor learning; it is especially useful for balance-related exercise effects in connection with various virtual sports programs. Thus, it enables elderly people to improve their obstacle gait and manage their health with respect to falls in a continuous and active manner.

This study used, the BBS and FRT as static balance ability assessments, the TUG test as a dynamic balance ability assessment, and measurement of CV and the MVHC for kinematic changes related to obstacle gait to investigate the effects of the Nintendo Wii Sports program and lumbar stabilization exercise on elderly women's balance ability with respect to falls and kinematic changes related to obstacle gait.

The results of the present study showed that the BBS, the FRT, the TUG test, CV, and MVHC were significantly improved. Consistent with the present study, Rose and Clark¹⁹⁾, report that elderly people who experience falls exhibited significant improvements in their BBS scores and TUG test results after visual feedback balance exercise. Meanwhile, Chen et al.²⁰⁾ and Madureira et al.²¹⁾ report that FRT and TUG test results improved significantly in elderly participants as a result of lower-limb power rehabilitation using interactive video games; this is also consistent with the present results in that balance training for elderly women significantly increased BBS score by 5.5 points in the experimental group and reduced the TUG test time by 3.65 s. In addition, Park and Lee²²⁾ report that elderly people were significantly slower in obstacle negotiation than young adults. Choi and Yoon²³⁾ report that elderly women tend to progressively increase the speed at which they negotiate obstacles 0%, 30%, and 50% of the length of their lower limbs after 12 weeks of aquatic exercise. Meanwhile, Kim and Yu²⁴⁾ report that MVHC decreased in elderly women after aquatic exercise. These 3 studies are somewhat consistent with the present results.

The LSE group performed their exercise on a stable floor, which increased their trunk muscle strength, improving their static balance ability. Meanwhile, the NWS group performed their exercise on a relatively unstable floor under various virtual conditions according to their reaction to visual and audio feedback, increasing their mobility and thus improv-

ing dynamic balance ability. In addition, the improved static balance ability due to increased trunk muscle strength in the LSE group and improved balance ability by stimulus reception from their vestibular system through various stimuli from virtual environments and proprioception improved their obstacle negotiation ability in various environments.

In summary, the 8-week NWS program improved the physical balance and obstacle negotiation abilities of elderly women to the same extent as LSE. Therefore, Nintendo Wii Sports is an effective home support exercise programs to prevent obstacle-related falls in the elderly.

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REFERENCES

- 1) Rubenstein LZ, Josephson KR: Falls and their prevention in elderly people: what does the evidence show? *Med Clin North Am*, 2006, 90: 807–824. [Medline] [CrossRef]
- 2) Stalenhoef PA, Diederiks JP, Knottnerus JA, et al.: A risk model for the prediction of recurrent falls in community-dwelling elderly: a prospective cohort study. *J Clin Epidemiol*, 2002, 55: 1088–1094. [Medline] [CrossRef]
- 3) Berry SD, Miller RR: Falls: epidemiology, pathophysiology, and relationship to fracture. *Curr Osteoporos Rep*, 2008, 6: 149–154. [Medline] [CrossRef]
- 4) Nevitt MC, Johnell O, Black DM, et al. Study of Osteoporotic Fractures Research Group: Bone mineral density predicts non-spine fractures in very elderly women. *Osteoporos Int*, 1994, 4: 325–331. [Medline] [CrossRef]
- 5) Cromwell RL, Newton RA, Forrest G: Influence of vision on head stabilization strategies in older adults during walking. *J Gerontol A Biol Sci Med Sci*, 2002, 57: M442–M448. [Medline] [CrossRef]
- 6) Blake AJ, Morgan K, Bendall MJ, et al.: Falls by elderly people at home: prevalence and associated factors. *Age Ageing*, 1988, 17: 365–372. [Medline] [CrossRef]
- 7) Chen HC, Ashton-Miller JA, Alexander NB, et al.: Stepping over obstacles: gait patterns of healthy young and old adults. *J Gerontol*, 1991, 46: M196–M203. [Medline] [CrossRef]
- 8) Spirduso WW, Francis KL, MacRae PG: Physical dimensions of aging, 2nd ed. Champaign: Human Kinetics, 2005.
- 9) Barbeau H, Visintin M: Optimal outcomes obtained with body-weight support combined with treadmill training in stroke subjects. *Arch Phys Med*

- Rehabil, 2003, 84: 1458–1465. [[Medline](#)] [[CrossRef](#)]
- 10) Maclean N, Pound P, Wolfe C, et al.: Qualitative analysis of stroke patients' motivation for rehabilitation. *BMJ*, 2000, 321: 1051–1054. [[Medline](#)] [[CrossRef](#)]
 - 11) Deutsch JE, Brettler A, Smith C, et al.: Nintendo wii sports and wii fit game analysis, validation, and application to stroke rehabilitation. *Top Stroke Rehabil*, 2011, 18: 701–719. [[Medline](#)] [[CrossRef](#)]
 - 12) Kim EK, Kang JH, Lee HM: Effects of virtual reality based game on balance and upper extremity function in chronic stroke patients. *J Spec Edu Rehabil Sci*, 2010, 49: 131–149.
 - 13) Song CH, Shin WS, Lee KJ, et al.: The effect of a virtual reality-based exercise program using a video game on the muscle strength, balance and gait abilities in the elderly. *J Korean Gerontol Soc*, 2009, 29: 1261–1275.
 - 14) Tinetti ME, Ginter SF: Identifying mobility dysfunctions in elderly patients. Standard neuromuscular examination or direct assessment? *JAMA*, 1988, 259: 1190–1193. [[Medline](#)] [[CrossRef](#)]
 - 15) Imai A, Kaneoka K, Okubo Y, et al.: Trunk muscle activity during lumbar stabilization exercises on both a stable and unstable surface. *J Orthop Sports Phys Ther*, 2010, 40: 369–375. [[Medline](#)] [[CrossRef](#)]
 - 16) Bovonsunthonchai S, Hiengkaew V, Vachalathiti R: Obstacle crossing characteristics in the healthy young female and elderly female subjects. *Sriraj Med*, 2012, 64: 52–56.
 - 17) Sparrow WA, Shinkfield AJ, Chow S, et al.: Characteristics of gait in stepping over obstacles. *Hum Mov Sci*, 1996, 15: 605–622. [[CrossRef](#)]
 - 18) Wang TM, Chen HL, Lu TW: Effects of obstacle height on the control of the body center of mass motion during obstructed gait. *JGIE*, 2007, 30: 471–479.
 - 19) Rose DJ, Clark S: Can the control of bodily orientation be significantly improved in a group of older adults with a history of falls? *J Am Geriatr Soc*, 2000, 48: 275–282. [[Medline](#)]
 - 20) Chen PY, Wei SH, Hsieh WL, et al.: Lower limb power rehabilitation (LLPR) using interactive video game for improvement of balance function in older people. *Arch Gerontol Geriatr*, 2012, 55: 677–682. [[Medline](#)] [[CrossRef](#)]
 - 21) Madureira MM, Takayama L, Gallinaro AL, et al.: Balance training program is highly effective in improving functional status and reducing the risk of falls in elderly women with osteoporosis: a randomized controlled trial. *Osteoporos Int*, 2007, 18: 419–425. [[Medline](#)] [[CrossRef](#)]
 - 22) Park SY, Lee YS: Kinematics of the lower limbs during obstacle crossing performed by young adults and elderly. *J Phys Ther Sci*, 2012, 24: 941–944. [[CrossRef](#)]
 - 23) Choi PH, Yoon SH: The kinetic and kinematic effect of a 12-week aquatic exercise program on obstacle gait in older women. *Korean J Sport Biomech*, 2010, 20: 129–137. [[CrossRef](#)]
 - 24) Kim SB, Yu YJ: The characteristics of obstacle gaits in female elders after 12 weeks of and aquatic exercise program. *Korean J Sport Biomech*, 2009, 19: 539–547. [[CrossRef](#)]