Effects of balance training incorporating with a kinect-based exergame on mediolateral postural sway in older adults with balance impairment: A pilot study

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Abstract

Background: Older adults with balance impairment have reduced lateral balance control in dual task situations. Previous study showed that a virtual reality training intervention such as Kinect-based game exercise can improve balance and cognitive function, however, there has no reports focused on the effect of a Kinect-based game exercise on dual task balance performance.

Objectives: To investigate the effect of balance training with additional Kinect-based game exercise intervention on mediolateral postural sway, while performing dual tasks, in older adults with balance impairment.

Materials and methods: Ten older adults with balance impairment, were recruited from community. They were divided into two groups; control group received conventional balance training, experimental group received conventional balance training together with Kinect-based game exercise training. Both groups had 4 sessions of exercise, 45 minutes each, and twice a week for 2 weeks. Mediolateral sway data were collected while performing a verbal place naming task at pre- and post-training using Wii Balance Board with MFU static balance test software, under 4 different conditions including semi-tandem standing with eyes closed and eyes open, and feet together with eyes closed and eyes open. All data were compared between groups and within group using Mann Whitney U test and Wilcoxon signed-rank test by STATA software.

Results: The results showed no significant decrease in mediolateral postural sway and no increase in number of correct answers in all conditions after training both between groups and within group.

Conclusion: Balance training with additional Kinect-based game exercise, for a total of 3 hours, twice a week for 2 weeks has no effect on mediolateral postural sway while performing dual tasks in older adults with balance impairment.

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Introduction

Balance impairment is an important risk factor for falls in older adults which can cause movement limitation, injuries and other problems such as fractures, and a decreased quality of life.[1] The physiological changes and decreasing in brain function in older adults affects postural stability, thus, older adults' postural stability deteriorates every year.[2] A previous study showed the effect of dual tasking on postural stability in older adults, especially for those with balance impairment. The recovery of balance was found to be slower and less efficient in balance-impaired older adults when simultaneously performing a cognitive task.[3] Dual tasking affecting mediolateral (ML) postural sway is associated with an increased risk of falling in older adults.[4] Falls often involve lateral body motion, and hip fractures occur most frequently in association with lateral falls.[5]

Improving balance in older adults, in order to improve quality of life, is one of the most important goals in physical therapy. Prata et al. 2012 reported that the ability to balance is associated with level of functional independence among older adults as balance impairment affects gait, and balance control, while performing activities in daily living.[6] Functional motor capacity in older adults should be improved or maintained throughout their life.[7] Balance training can be conducted using various therapeutic approaches such as dual task training,[8] and sensory-specific balance training.[9] Training can be time-consuming, therefore patient non-adherence with therapy is a major barrier to rehabilitation. A previous study supported brain changes in cortical area after balance training for 2 weeks (for a total of 3 hours) which indicated motor learning occurs in brain network.[10] However there is evidence that patients frequently do not meet sufficient "dosage" of movements required to induce neuroplastic adaptation underlying behavioral improvement.[11]

Using of virtual reality (VR), an interactive games or "exergames", as a complementary tool in rehabilitation makes it possible to practice activities within enriched, secure, and challenging environments, thereby favoring motor learning and neural plasticity.[12] System components in virtual reality training combine to create sensory illusions that produce, a more or less believable, simulation of reality. VR simulates natural events, and social interactions, can be used to augment bilateral training and constraint-induced movement therapy techniques.[13] The exergames are designed to have an empirical basis for increasing player engagement and motivation.[11] As an intervention, exergames can potentially improve physical function in older adults, with few reported adverse events.[14] Kinect games is the most popular exergames system used for rehabilitation. Kinect exergames encourage full-body movement activities, player motivation, and provide challenging options for a variety of rehabilitation purposes.[15]

Applications of Kinect games in elderly care can be grouped into two categories including fall detection, and fall risk reduction.[16] Kinect exergames training promotes improvements in balance and cognitive function in older adults.[17,18] In the real world, older adults must frequently do two things at the same time, a motor and a cognitive task, such as walking while talking. Many older adults have reduced postural stability while performing a dual task. Physical therapists aim to improve balance control in older adults with Kinect game training, however, no previous study has reported the effect of balance training incorporating a Kinect-based exercise game to promote balance control while performing a dual task. It is therefore interesting to investigate the effect of balance training, with an additional Kinect-based exercise game, on improving dual task balance performance in older adults with balance impairment.

Materials and methods

Study design

A pilot study experimental design with randomized controlled trial.

Participants

Ten older adults, aged between 60-74 years, with balance impairment (Berg Balance Scale; BBS of less than 45 from 56) were recruited. Inclusion criteria included being able to stand by themselves without any assistance. Participants with cognitive impairment were excluded (Mini-Mental State Examination-Thai; MMSE-Thai >16 for older adults with no education, >20 for older adults with

primary school education, >23 for older adults with education higher than primary school). Participants with an excessive fear of falling were also excluded (Thai Fall Efficacy Scale-International; Thai FES-I < 23). Furthermore, participants with a past medical history which may affect balance such as stroke, cerebellar ataxia, or vestibular disorder were not recruited. They were also excluded if they self-rated themselves at higher than 5 on a pain scale of 1 to 10.

The study was conducted at Nanglae; Moo 3 and 13 central village auditorium, Chiang Rai. All participants gave their informed consent before participating. Study protocol was approved by the Mae Fah Luang University Ethics Committee.

Procedure

A total of 32 participants were assessed for eligibility. There were 22 participants excluded because they were not met the inclusion criteria. Thus, 10 participants were randomized into two groups by a lottery system as shown in Figure 1. Control group received a conventional balance training program adapted from Silsupadol et al. 2006. The training session followed Gentile's taxonomy of movement tasks.[8] Thus, the training used four separate training stations and sequence of training stations were according to degree of difficulty; 1) stance with no manipulation (semi-tandem with eyes open or closed), 2) stance with manipulation (semi-tandem with eyes open or closed and arm position alteration), 3) stance with no manipulation (drawing letters with left and right foot), and 4) stance with manipulation (standing with a narrow base of support then reaching in different directions, or throwing a ball). Experiment group received the same conventional balance training program with additional Kinect-based exercise games. Games chosen were based on a previous study,[17] and included Kinect sports and Kinect sports bowling. Both groups received 2 weeks of training, comprising 45 minutes training sessions, twice a week. The experiment group received 25 minutes of conventional balance training program plus 20 minutes Kinect-based game exercise. Both groups performed training with individual practice under supervision of the researcher.

The mediolateral postural sway data and number of correct answers were collected pre- and post-training using Wii Balance Board in conjunction with MFU static balance test software, under four different conditions. This included semi-tandem standing with eyes closed and open, and feet together with eyes closed and open. A previous study reported that Wii Balance Board is a valid and reliable device for the assessment of balance performance in older adults compared to a standard laboratory grade force plate.[19] This is supported by another study demonstrating the excellent reliability of Wii Balance Board with MFU static balance software for assessment of static balance.[20] For pre- and post-comparative analysis and between group comparative analysis, mean value of data collected from three trials of 30 seconds standing was used for statistical analysis. Participants were instructed to stand still on Wii Balance Board and keeping their arms by their sides while performing an interactive verbal place naming task.[21] An audio device recorded the responses, and numbers of correct answers (words) were used for statistical analysis. All assessments were conducted by the same researcher.

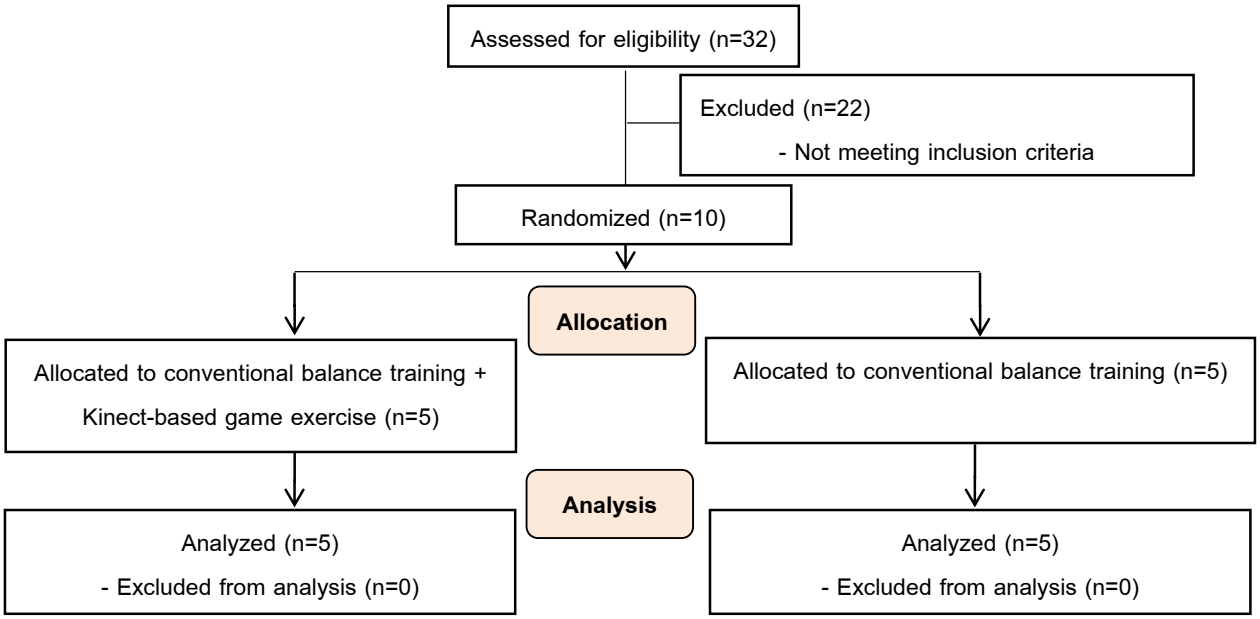


Figure 1 *A temporal flow chart of the study design.*

Statistical analysis

Normal distribution of data was determined by Shapiro-Wilk test. STATA software was used to analyze the mediolateral postural sway data and numbers of correct answer data. Thus, data was compared between groups using Mann Whitney U test and within group using Wilcoxon signed-rank test. For baseline characteristics between groups comparison, Chi-square was used to analyze gender and education (years) data, independent t-test was used to analyze age, BMI, BBS, Thai-MMSE and Thai FES-I data. An alpha level of 0.05 was chosen to determine statistical significance.

Results

Participant characteristics are shown in Table 1. There was no significant differences between experiment and control groups with respect to age, BMI, BBS, Thai-MMSE, but a significant difference between the two groups was found in Thai FES-I. Thai FES-I is a questionnaire for assessing fear of falling. A score of more than 23 indicates a high anxiety of falling.[22] Because scores of both groups indicated low concern about falling, the difference of Thai FES-I between groups was not relevant to the study.

Table 1 Participant characteristics.

Variable	Mean±SD		*p*-value
	Experiment group (n=5)	Control group (n=5)	
Gender			
Male	1 (20%)	2 (40%)	1.00
Female	4 (80%)	3 (60%)	
Education (years)			
16 years	1 (20%)	0 (0%)	1.00
9 years	0 (0%)	1 (20%)	
4 years	3 (60%)	2 (40%)	
No education	1 (20%)	2 (40%)	
Age (years)	67.6±6.02	69.2±5.63	0.57
BMI (kg/m^2)	23.36±2.67	21.87±2.36	0.83
BBS	44.0±0.00	41.2±3.56	0.12
Thai-MMSE	27.6±5.37	24.2±5.37	0.47
Thai FES-I	16.4±0.89	19.6±2.30	0.02*

** p<0.05 with independent t-test*

As a consequence of the intervention, no significant decrease in mediolateral postural sway was found between groups or within group for all conditions, For the condition with feet together with eyes open condition, however it was found that there was a significant increase in mediolateral postural sway after training between groups (p<0.05) as shown in Table 2. In addition, no significant increase was found in the number of correct answers between groups or within group for all conditions (Table 3).

Table 2 Mediolateral postural sway (cm.)

	Experimental group (n=5)				Control group (n=5)				Mean different	*p*-value
	Pre-test	Post-test	Different	*p*-value	Pre-test	Post-test	Different	*p*-value		
Semi-tandem standing with eye closed	3.85±2.67	3.78±3.31	0.07±0.93	0.500	2.99±2.84	5.05±2.67	-2.05±4.26	0.345	-2.12	0.347
Semi-tandem standing with eye open	4.92±2.53	3.03±1.78	1.87±2.34	0.079	3.87±3.47	4.29±2.55	-0.43±3.44	0.500	-2.31	0.464
Feet together with eye closed	0.94±0.70	1.86±1.36	-0.92±1.81	0.225	1.92±1.59	1.56±0.88	0.36±1.54	0.893	1.28	0.347
Feet together with eye open	1.00±0.81	2.02±1.32	-1.01±0.81	0.080	1.55±0.93	0.96±0.74	0.58±0.81	0.138	1.59	0.016*

** Significant different between groups; p<0.05 with Mann Whitney U test*

Table 3 Number of correct answers (words).

	Experimental group (n=5)				Control group (n=5)				Mean different	*p*-value
	Pre-test	Post-test	Different	*p*-value	Pre-test	Post-test	Different	*p*-value		
Semi-tandem standing with eye closed	4.40±4.10	4.80±3.56	0.40±1.67	0.781	4.20±1.10	3.60±1.52	0.60±1.82	0.584	1	0.523
Semi-tandem standing with eye open	3.60±4.04	3.40±2.96	0.20±1.30	0.781	3.60±2.07	5.00±1.22	-1.40±1.52	0.102	-1.60	0.089
Feet together with eye closed	7.80±4.32	9.80±4.43	-2.00±2.55	0.102	5.60±1.14	6.60±1.14	-1.00±1.41	0.159	1.00	0.592
Feet together with eye open	4.60±3.51	7.00±4.69	-2.40±2.07	0.057	4.60±1.14	5.20±1.64	-0.60±2.30	0.494	1.80	0.292

Discussion

Kinect-based games are a popular tool for rehabilitation. Previous studies supported the benefit of Kinect-based game exercise in rehabilitation. It is used in rehabilitation for elderly stroke, and Parkinson's, patients as it encourages whole body movement including upper and lower limbs. It can also challenge participant's balance ability while moving in different directions because center of mass is located at the level of the second sacral vertebra. The game is an external driver for patients' motivation and continued participation. Patients can imagine that they are the actors in game and are game controller. The game simulates a three dimensional real world in virtual reality, thus, they can imagine that they are in a real situation in difference locations. It can therefore be very helpful in the hospital or clinical setting where patients cannot go outside to practice in real environments and situations. Practicing in the real environment is very important to motor skill learning as it can stimulate neural plasticity in the brain to learn, or re-learn, a motor task.

Many interventions are used for balance training. Virtual reality training can activate cerebral cortex and improve spatial orientation capacity of patients, thus facilitating the cortex to control balance and increase motion function.[23] Kinect games drive whole body movement and challenge balance control, promoting motor adaptation during postural tasks. A previous study reported that balance training reduced spinal reflex excitability by increasing supraspinal induced presynaptic inhibition. Consequently, adaptation after balance training is a reduction in cortical involvement.[10]

Performing two tasks simultaneously such as counting backward while standing or performing an interactive verbal place naming task, could be a dual task interference, with both a postural and cognitive task, where the attention controlling both tasks is divided. If brain pays attention to task 1 more than task 2, it could cause a decrease in performance of one or both tasks as explained by capacity theory. The lateral prefrontal cortical structures are recruited when dual-tasking, involving more serial response selection.[24]

Research question of the present study was whether balance training with additional Kinect exercise games can improve balance control in dual task situations. It was found that balance training with additional Kinect exergames did not decrease the mediolateral postural sway while performing a dual task in older adult with balance impairment. No change was found in either mediolateral postural sway or number of correct answers, which comprised the postural and cognitive task components. In contrast, Beaulieu-Boire et al. (2015) found improved balance control after training with Kinect games,[17] and Vernadakis et al. (2014) also reported improved balancing ability after training in previously injured young competitive male athletes.[25] There are, however, differences in testing condition between our study and previous one. They assessed balance in single task condition but ours assessed balance in a dual task condition, which is more complex and difficult than a single task condition. In addition, it could be suggested that duration and intensity of the intervention was insufficient to cause a significant training effect. Although

a previous study reported brain changes after balance training for 2 weeks.[10] Total hours balance training of study was 3 hours with intensity and duration induced a change the brain in physiological level. There was no change in behavioral level observed in this study. Other studies suggest that 10 to 12 hours is more suitable duration and intensity to induce a change in performance.[8] Thus, it could be suggested that total of 3 hours is insufficient to cause a reduction in attention paid to cognitive task, resulting in no improvement to postural stability, as explained by capacity theory.

Motor training induced learning caused changes to physiological plasticity within primary motor cortex. Kleim et al. (2006) suggested that there are training-dependent increases in amplitude of motor-evoked potentials and motor map reorganization.[26] Kinect-based exercise game in this study was designed to improve balance control in older adults with balance impairment. Based on the principle of experience-dependent plasticity, it could be based on second principle where training drives a specific brain function which can lead to an enhancement of that function.[27] Motor skill acquisition could be divided into 3 stages including cognitive, associative, and autonomous stages.[28] In autonomous stage, participants can learn to effectively perform both a postural and a cognitive task simultaneously. In this study, it could be suggested that training effect did not reach the autonomous stage. Long term effect of training is also unknown because we assessed only participants' balance immediately after completion of training sessions.

Many studies, however, support the benefit of Kinect exergaming training because training with gaming patterns results in a 30% reduction of falls.[29] Physiological data suggest that gameplay can induce neuroplastic reorganization leading to long-term retention and transfer of skill. Importantly, gaming provides choices, rewards, and goals that lead to increased motivation and engagement.[10] Effects of training with a longer duration and variety of intensity would be further on studied.

Conclusion

Three hours of balance training, with additional Kinect-based exercise games, has no effect on mediolateral postural sway while performing dual tasks in older adults with balance impairment.

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