Effect of Virtual Reality-based Training Program on Patients with Mild Cognitive Impairment

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Abstract: Fall is defined as an abrupt, unexpected event where one comes to rest on the ground or floors. This is one of the major causes of disability among adults and elders, inducing reduced mobility and low quality of life. The elderlies living alone were in high-risk of frequent falls, thus, various rehabilitation interventions for them were needed including exercise programs, which was found to be useful. In this study, an alternative, which is virtual reality, was used as a viable intervention for fall prevention. Specifically, it used the Nintendo Wii, a small and cheap personal game console, on the exercise physicomental playing. The aims of present studies were to define through quantitative measuring the effect of virtual reality programs in Wii sports games on the balance of elderly people who are living alone and at the risk of falling. Computerized dynamic posturography (CDP) was applied as the data collection procedure to quantitatively measure the effect of virtual reality programs in Wii sports games on the balance of elderly people. The study included 30 patients over 65 years of age who lived alone and had a self-reported balance deficit or fall history before the evaluation. The participants were casted at random to empirical (n=15) or control group (n=15). The empirical group kept three Wii balance exercises composed by forty minutes per week totalizing for 12 weeks. The control group have not performed any empirical program other than conventional recreational therapy. This study used a CDP to evaluate all patients at the starting and termination point of the study. In addition, all subjects were assessed by the Short Form of Geriatric Depression Scale (GDS) to screen their depression level and to measure the therapeutic effects. A statistical significance was verified among patients about treatments utilizing t-test. After 36 experimental times, the sensory organization test showed significant differences in the fifth and sixth conditions and a vestibular ratio of the empirical group from the basis to the after-test. In opposition, little statistically compelling discrepancy was detected in control groups. The empirical group revealed a compelling betterment in the GDS following the program compared to the control group. This study demonstrated quantitatively that a virtual reality exercise program, such as in Wii, may improve the balancing ability of older people who live alone and at high risk of falls. The Wii program, which does not take up much space, is inexpensive, easy to move and install, and can be widely applied to physical therapy for elderly patients who live alone and at high risk of falling.

Keywords: Balance, Posture, Virtuality, Exercise

1. Introduction

Falling including the anxiety about fallings causes discomfort, depression, and poor quality of life, which bring about a great disability for the elderly[1]. This is a very worrying matter considering the fact that falls could have occurred within about 30% of the elderly. Falls must be the main cause of hospitalization in this group population of high age[2]. In the elderly population, as the age increases,

about 94.7 % of them have the proprioception, visual, and vestibular functions involved in postural control be degraded and muscle strength weakened[1]. So that the reflexive ability to cope with sudden changes in motion is reduced, resulting in an easy fall.

Aging is associated with decay of the hair cells and otoconia, decline of vestibular afferents, and dropping numbers of cells in the vestibular nuclei. The vestibular nucleus cell numbers of nearly two-thirds of the elderly are 50 percent lower than they were young[3]. The elderly is also liable to other central neurodegenerative growth. The sensory power is finally altered in elderly people. Furthermore, information which is got from the sensory terminal organs is many times interpreted poorly by the central nervous system. About 63 % of populatins over 65 years of age who live homely are at the risk of such degeneration of nervous system and 30% of them fall at least once a year.

It is evaluated that the number of lonely elderlies could progress steadily, and be doubled by 2040[4]. The lonely elderlies are more affected to social, economical, physical, and intellectual difficulties than the elderlies who were living with their family or others. Several domestic studies have shown that 33.3% of lonely elderly people felt loneliness, which was associated with cognitive deterioration, depressive mood and eventually frequent falls[5]. Therefore, the lonely elderly are classified as high-liability group of frequent falls, so diverse mental and physio-social activities are needed to hinder them[6].

Exercise therapy to prevent and treat equilibrium disorders and falls includes motor therapy that strengthens the posture stability of proximal muscles and physical therapy that applies regulated operative exercise. However, performing these physical treatments always requires continuous and professional guidance from physical therapists. In addition, there are many restrictions on practice due to lack of motivation on account of fatigue and depression, which are chronic mental problems of elderly patients living alone, and many give up halfway. Therefore, it is necessary to develop an exercise therapy program in which patients can easily follow without losing interest, relatively free from spatial and cost issues.

With the recent development on technology and PC programs, physical therapy and rehabilitative mediations rooted from virtual realities (VR) have been brought out for the treatment of elderly diseases. VR indicates to a PC-based estimation setting that enables customers to experience identical to reality. It is an interactive technically manipulated simulation that provides reality experiences through various feedbacks[7]. It is said that virtual reality system can control the movement of players by exchanging various feedback through various senses such as vision and hearing while performing pre-set tasks such as playing games in virtual reality[8]. Comprised of a computer simulation environment and interactive video game functions, the virtual reality exercise program inspires competition, and induces motivation and interest among gamers. It has been reported that participation in exercise therapy using virtual reality increases the number and concentration of exercise and improves well-being more than traditional exercise[9].

Despite these assets, however, due to several limitations, such as high cost and huge size, the existing VR systems were not be extensively applied to patients clinically. For this reason, virtual reality exercise program that can be easily followed in the patient's personal space or at home is needed. Recently, there is increasing interest in whether home game consoles applying virtual reality such as Xbox Kinect, PlayStation VR, and Oculus VR can be used for treatment. Among them, Nintendo Wii (Nintendo Co.,Ltd., Kyoto, Japan; Wii) which is a marketable personal game for the first time, is becoming interested in being able to be used easily in such exercise training. As a kind of video game console, Wii was known to be played with a simple usage direction where VR system is realized by a TV monitors. They combined motion in space with computer simulation graphics and interactive video game functions.

The Wii consoles are cheap and lesser in size, making it easy to build or carry in care centers and homes. The Wii game console is designed to utilize wireless multipurpose controllers to apply a

movement detection system so that users can interact with their avatars displayed on the screen. The controllers are equipped with dynamic detectors which detect alterations in courses or speeds, and responds to changes in acceleration . Since Wii is a representative example of a modest, cheap, and with ease available VR machines, Wii is estimated to stimulate the attentiveness of players who increase the therapeutic effect by putting more effort into exercise through games.

Until now, studies on virtual reality exercise programs using Wii game consoles have mainly been conducted on rehabilitation of stroke patients and cerebral palsy. The effectiveness of the Wii game machine was said to be good in rehabilitation exercises to improve the balance ability of patients. After eight weeks of virtual reality exercise composed of several Wii-Sports' games like tennis, the physical activity of Parkinson's disease patients was higher than before the start. It was concluded that the virtual reality exercise therapy program with Wii was effective in improving the cognitive ability and qualities of lives (QOL) of the subjects by observing the tendency of improvement in motor ability and depression[10]. Though this was not a quantitative test using a dynamic posture meter because it used a subjective scale and different subjects, it accorded with the results of this study in that the virtual reality program showed the effect of improving the balance of patients with neurological diseases.

There have been scarcely controlled studies which assessed the influence of Wii on the elderlies who live alone and who often fall until now. Furthermore, only few studies have evaluated the same research using quantitative means of measurement such as posturography. Therefore, the need for research is being raised, aiming to quantitatively analyze the effect of virtual reality practice program based on Wii on balance functions of the elderlies using the computerized dynamic posturography.

Various bedside tests for assessing balance clinically are present. The firstborn, and still done, is Romberg's test. Other cases included the Berg Functional Balance Questionnair and the Tinetti balance-and-gait test. They are stress-free to perform but have the difficulties about ceiling effects and reduced specificities. Serviceable methods have been required to develope for measuring balance more correctly. Computerized dynamic posturography (CDP) is a technique involving the quantification of ground reaction powers from which the center of weight and sway may be computed. The easiest device is a force plate. A more innovative kit is EquiTest; a diagnostic instrument that quantifies the sway in numerous conditions. The CDP can theoretically distinguish between diverse causes of postural disorders including visual, vestibular, and proprioceptive balance capability of patients[11].

Using the EquiTest, balance is evaluated using sensory organization test (SOT) calculation. Numerous studies have proved the link between deteriorated SOT equilibrium scores and the occurrence of falls in all age adults. In normal adults (mean age 46), the occurrence of many falls within a five-year period was considerably linked with lesser SOT equilibrium scores. Likewise, in elderly adults, SOT composite scores have been considerably lower in patients with falls matched to non-fallers. The collective proof from these and other tests proposes that balance valuation using the EquiTest SOT is a robust predictor of risk of falls. Therefore, the improvement of the equilibrium function after treatment with Wii can be revealed more accurately and quantitatively using CDP

Older lonely people are more susceptible to economical, social, and mental problems than older people living with family members. It is known that there are more depression and loneliness among elders living alone that those who live with their families. In other domestic studies, 33.3 % of elderly people living alone reported loneliness, which was related to cognitive decline. Depression can also more than double the risk of dementia. Elderly people who live alone are vulnerable to loneliness, helplessness, and depression, because of lack of social relations and communication. To motivate those people in loneliness and depression, medical services that will increase their willingness to receive treatment should be provided.

The hypotheses of this study are as follows:1) Can Wii-based VR program improve the equilibrium function of old people who are living alone and at the risk of falls? 2) Can it alleviate depression in the subjects? In summary, this study will determine if the Wii program will be as effective as other expensive

and large VR programs in the treatment of old people who are living alone and at the risk of falls?

2. Materials and Methods

2.1 Subjects

The subjects of this study were registered from April to December 2019. They were from communities registered in public administration, including three regional dementia centers in Cheonan. All study subjects were recruited using the criteria that they must be 65 years of age or older, living alone, and have a self-testified balance shortage or a past of a fall prior to the study. Further inclusion criteria encompassed: being ambulant and moving independently, lack of mental deficiency (MMSE >24/30), and could understand and follow simple trainings; no loss on otoscopic/otomicroscopic assessment; a pure tone threshold which is consistent with the patient's age; and an average visual sharpness with or without curative lenses.

The Falls Efficacy Scale-International (FES-I) should be directed to define the participants' subjective anxiety of falling with regard to individual activities of daily living[12]. All subjects underwent neurological examination, and MRI or CT of the brain. Rejection criteria were any diagnoses of dementia, musculoskeletal disorders, Parkinson's disease, treatment with antidepressant, strong analgesic, muscle-relaxing, or anticonvulsant agents. Patients with chronic medical diseases (such as diabetes, cardiovascular diseases, osteoporosis, arthritis) must get consent to exercise. They received medical permission from a general medical practitioner who was provided with absolute and relative contraindications on exercise at the Department of Sports Medicine at Dankook University[13].

In this study, 37 subjects were recruited and only a total of 30 subjects participated, except for the seven subjects, diagnosed not suited for the experiment or who refused to participate in the study. The investigational groups (N=15) and control subjects (N=15) were indiscriminately allocated to do the study. In the case of control group, patients with similar conditions to the experimental group were placed in relations of age, period of disease, rigorousness of symptoms, and exercise patterns. The investigational group did a total of 12 weeks Wii balance training three times per week comprised for 40 minutes. The control group had not joined in any exercise program other than the conventional recreational therapy. This study was approved by Dankook University Hospital's institutional review board (2018-08-005-009). The study was carried out pursuing the Helsinki Declaration (1983) criteria for the ethical consideration observed in the conduct of the study. All participants were advised about the plan subject of the study and that the outcomes can be used in another place. They were requested to sign a written informed consent statement prior to the beginning and evaluation of the program. The data were collected with the same subject conducting valuations and gathering data using identical apparatus. All pre and post-study calculations were led by the similar attributed physiologist with more than five years of experience interventions in prevention of fall. There is a schematic diagram to provide an overview of the entire research process[Fig. 1].

2.2 Nintendo Wii

Wii-Fit and Wii-Sports software manufactured by Nintendo (Nintendo Co., Ltd., Kyoto, Japan) were adopted for VR game program. The Wii-Sports console contains a structure that let avatars (Mii) to perform on the monitor as portion of the Wii-Fit program, and moves along the movement of participants upright on the balance panel with weight sensors assigned. In sequence, the Wii-Balance Board provides not only several visuo-auditory feedbacks on gesture, but also vibrational responses to numerous movements via the remote control. The Wii-Balance Board's measuring devices were not modified from the original Nintendo release[14]. Participants in the experimental group exercised individually three

times a week for 40 minutes at a time. They exercised a total of 120 minutes a week, or 36 times along the 12-week program. In each terms, an exercise did 30 minutes on the Wii Fit Balance and 10 minutes on the Wii-Sports games.

The experimental group were guided to operate like in real sports while playing Wii sports games with remote controls in their hands. After providing a full description of the VR game and demonstrating it to all participants, the experiment was initiated. For those who have difficulty learning the game, they have encouraged participation in the intervention by providing repeated demonstrations and explanations. As the intervention proceeded, a physical therapist stayed nearby and continued safety management in case of a fall. Whenever a participant was tired or dizzy, he/she was drilled to take adequate break and go back to the exercise.

At the start, five elderly people, who declined to use the technology because game difficulty is too high to perform, were proposed to play with easier difficulty and shorter games as the alternative. All groups kept a record to report their growth and scores. They were conducted to make a note whether or not each game session was performed, the span of play period, the side effects, the deterioration of symptoms, and the difficulties. The therapists will collect all these data and analyze the satisfaction rate after the game.

2.3 Assessment with Computerized Dynamic Posturography

The measurement of equilibrium ability of subjects used a computerized dynamic posturography (CDP). All subjects were evaluated by CDP before the start of the test. A follow-up study was taken after the exercise twelve weeks later. The CDP used in this study is the SMART EquiTest® CDP (NeuroCom® Inc., San Carlos, CA, USA) which has been commercialized by Nashner since 1986. This inspection device consists of a moving visual surround, platform, and computer device. The platform, which is a tread plate, is allowed to move in the fore and aft direction, toe-up and toe-down directions, and the visual field moving separately, causing confusion in the visual field of the subjects or confusion in the perspective of the subjects by operating as if the tread were moving.

The EquiTest CDP was practiced in which the subjects stood on a force plate and a graphic surround is encircled. The feet were set straightforward ahead with a space of 15 cm between. The boards quantifies the force between the floor and the feet in a horizontal A-P direction and from that the sway can be evaluated. The patients among the control group were evaluated in six devided conditions (sensory organizing test). The sensory organizing test (SOT) of CDP selectively stimulates the physical sensation of the examinee. This test consists of six tests with a combination of conditions giving confusing vision by means of opening and closing eyes, moving the footrest, or moving the visual background. In the upright position on the tread plate, each test shall be conducted three times, 20 seconds each time, and their average shall be obtained as an equilibrium score. The equilibrium score is calculated by setting 0 point for perturbation above the maximum limit of 12.5°, which can be maintained around the ankle joint in the fore and aft direction, and 100 points for the state of total equilibrium and no perturbation. An equilibrium score (ES1-6) is calculated for each condition, that measures the center of gravity's sway or postural unstabilities under each of the three sessions of the six sensory conditions.

The scores were calculated on the amount of A-P sway matched to the maximum theoretical sway bounds of stability (8.5° anterior and 4° posterior). The score is evaluated by the succeeding formula: $ES = \{12.5° - (\theta max - \theta min)\}/12.5° \times 100\%$. In this formula, θmax designates the greatest A-P sway showed by the subject and θmin designates the least A-P sway. A score of 100 signifies flawless balance (no sway), and a score of 0 signifies a possible fall (sway surpasses limits of stability). If at whatever time during the trial, the subject took a step or required the help of the safety harness, the subject's equilibrum scores made a 0 for that test.

Conditions (COND) 1, 2 and 3 are examined under conditions such as when the eyes are opened or closed on a fixed tread plate, or when the background moves along a perturbation, causing confusion in vision. It tests whether normal vision is necessary to maintain the test subjects' balance and whether the brain can suppress inappropriate vision. COND 4, 5 and 6 are the addition of the conditions of the foot-plate moving according to the degree of agitation of the examinee to the above three conditions [Fig. 2].

The following sensory analysis can be performed by comparing these conditions:

-The somatic sensory ratio (SOM) looks at how much body movement increases when the help of vision disappears. The equilibrium scores of COND 2 were divided by the equilibrium scores of COND 1.

-The visual ratio (VIS) specifies whether the vision, excluding physical sensation, is effective if it is used to stand still. The equilibrium scores of COND 4 were divided by the equilibrium scores of COND 1.

-The vestibular ratio (VEST) sees if the vestibular function, excluding visual and physical senses, is normal. The equilibrium scores of COND 5 were divided by the equilibrium score of COND 1.

-The visual preference (PREF) sees if the brain can suppress inaccurate visual information and keep the body in balance. The values were obtained by dividing the equilibrium points of COND 3 and COND 6 by the equilibrium points of COND 2 and COND 5.

2.4 The Short Form of GDS

All subjects were assessed by the Short Form of GDS (Geriatric depression scales) to screen their depression level and to measure the therapeutic effects. The Short Form of GDS was developed by Sheikh & Yesavage (1986) as an assessment tool in the form of a questionnaire to evaluate the level of depression in older people. The items of the questionnaire reflect the logical, emotional, cognitive, physical, and social aspects in older people to examine the overall state of depression.

2.5 Statistics

The experimental results were analyzed by The IBM® SPSS® software platform. All data was proved to be normally distributed through the Shapiro-Wilk test. The mean and standard errors were measured for all presenting variables. The significance of each investigational and control subject groups before and after the experiment was tested using paired t-test. The level of significance was fixed at $p < .05$.

3. Results

There were no participants who dropped out and all thirty subjects completed the program.

[Table 1] shows the demographic features of a total of 60 subjects who joined the study. The mean age was 79.2±7.2 years in the investigational group and 78.5± 8.3 years within the control group. After finishing the program, the investigational group showed a significant advance in fear of falling (FES-I score), while the control group had no improvements.

At the start of the study, the features of the two groups did not show statistically significant changes. After finishing the study, the experimental group scores were significantly higher than before in condition 5 and 6 ($p < .05$). The changes of score in the control group before and after the experiment were not significant. When the difference in the change between the groups before and after the experiment were campared, the experimental group's equilibrium scores increased significantly in conditions 5 and 6 compared to those of the control group [Table 2]. It means that the experimental subject was standing well without losing balance despite the foot plate swinging back and forth.

Not any significant differences in the sensory ratio at the start of the experiment between the

investigational group and the controls were shown. At the finish of the experiment period, the VST scores in the investigational group were significantly increased (p < .05). No significant changes in the SOM, VST, VEST, and PREF of the control group after the end of the experiment were noted. The amounts of VST increase in the investigational group were significantly changed than the controls (p < .05). This indicates that the experimental groups' vestibular function, excluding visual and physical senses, is improved after the experiment as described in [Table 3].

The empirical VR-game group showed a substantial improvement in the depression scale after the program compared to the control group [Fig. 3]. Interestingly, 53 % of the subjects wanted to continue using Wii after the experiment, so as to be a satisfaction rate high. The hypothesis of "Can Wii game program alleviate depression in old fallers who are living alone?" was satisfied.
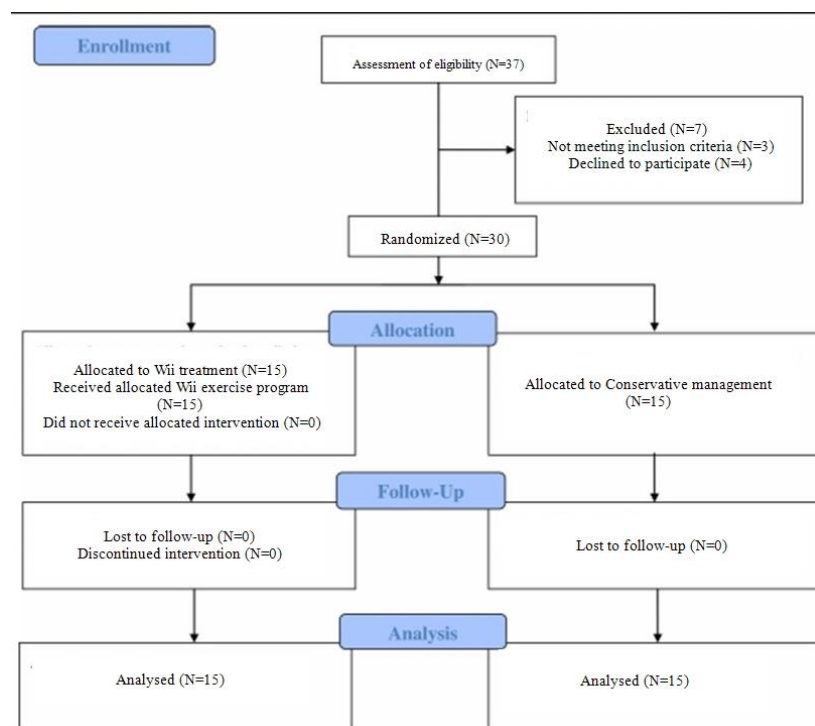
[Fig. 1] Participant flow sheet
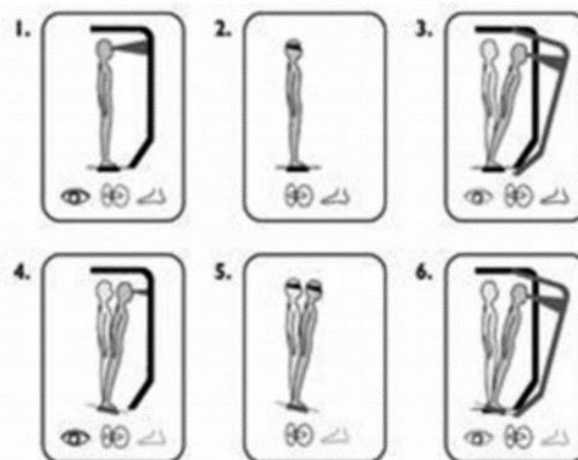
[Fig. 2] Sensory organization test (L. M. Nashner, Computerized dynamic posturography, 2001)

[Table 1] Starting point demographic features of all applicants reported by a form of median

Starting point demographic features	Investigational group (N=30)	Controls (N=30)	Between groups' p- value
Age, y	79 (74,84)	78(71,83)	.39
Sex			.59
Men, n (%)	12 (39.7)	8 (30.0)	
Women, n (%)	18 (60.3)	21 (70.0)	
Falls Efficacy Scale - International	33 (25,40)	32 (25,42)	.93
Short form of Geriatric Depression Scale	6 (5,7)	6 (5,7)	.96

[Table 2] SOT equilibrium scores beforehand and afterward test

COND (score)	Investigational group		Controls		Changes of scores	
	Before	After	Before	After	EX before-after	CONT Before-After
SOT one	93.9±3.8	92.9±3.8	92.6±4.4	92.5±4.8	.3±2.8	-1.1±3.2
SOT two	87.6±3.5	88.8±3.3	88.8±3.2	88.9±4.2	1.2±2.1	.1±3.8
SOT three	87.2±3.8	88.5±3.5	87.5±3.9	88.1±3.9	1.3±2.2	.6±2.8
SOT four	68.4±7.9	70.5±5.7	69.2±6.1	68.9±5.8	2.0±2.7	-0.3±2.8
SOT five	43.3±5.9	54.5±5.6	44.4±7.8	40.8±9.2	11.2±2.1*	-3.6±3.1
SOT six	37.6±6.6	53.8±7.8	37.5±8.2	36.5±8.1	15.8±1.9*	-1.0±2.3

means±standard deviations.
COND, conditions; SOT, The sensory organization test; EX, Investigational group; CONT, Controls.
*p< .05.

[Table 3] Sensory analyses ratio pre- and post-treatment

Sensory ratio (%)	Investigational group		Controls		Change of scores	
	Before	After	Before	After	EX before-after	CONT before-after
SOM	96.3±3.2	97.6±4.7	93.4±5.4	93.0±5.3	1.2±2.6	-0.3±1.8
VIS	77.1±4.4	74.8±4.8	75.6±6.1	74.5±5.9	-2.2±3.3	-1.1±3.5
VES	43.9±5.1	61.6±5.9	46.3±7.1	45.9±7.8	17.4±2.6*	-0.4±3.4
PREF	98.2±3.5	99.3±3.2	98.3±3.3	98.0±3.2	1.1±2.3	-0.3±3.0

Values are presented as mean±standard deviation.
EX, Investigational group; CONT, Control group; SOM, Somatic ratio; VIS, Visual ratio; VES, Vestibular ratio; PREF, Visual preference ratio
*p< .05.
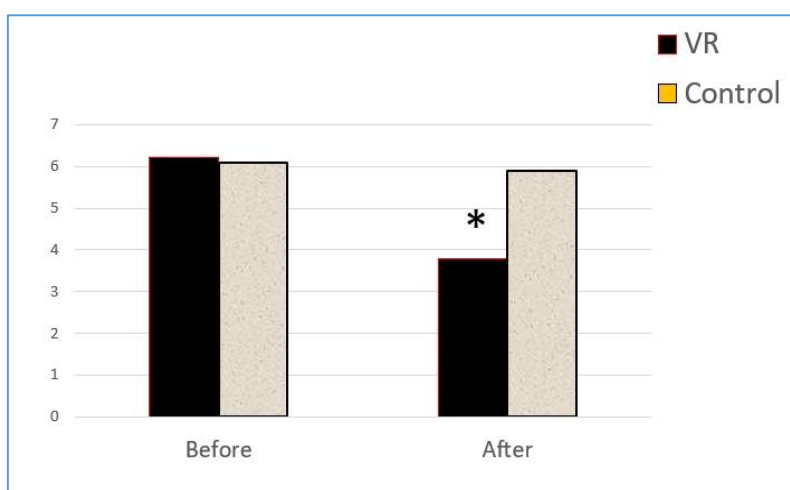
[Fig. 3] The Short form-GDS scores before and after the program. *p < .05.

VR, virtual reality treatment.

4. Discussions

The aim of this study was to study the influences of Wii, one of the small and simple virtual reality equipment, on the balance of the elderly people living alone. Previous studies mainly used subjective surveys or non-quantitative measurement such as standing-with-one-leg up as a measure of balance ability. In this study, a quantitative measurement study using a dynamic posturography was performed on faller patients, and such attempts have been rare so far.

This study demonstrated quantitatively that virtual reality exercise programs can have the effect of improving the balancing ability of elders living alone who fall frequently. The SOT 5–6 are considered as the best test elements to identify a vestibular disorders, either central or peripheral. Whenever the visual and proprioceptive stimuli are either absent or perturbed, the subjects used to rely on the vestibular system so as to preserve balance. [Table 2] shows that CDP test of the investigational group showed a substantial improvement in SOT conditions 5 and 6 after treatment. This is a sign that the experimental groups were standing well without losing balance despite the foot plate swinging back and forth. It could be taken as to indicate that the postural disorders in fallers are due to vestibular functions.

In sensory analysis, the VST scores in the investigational group were significantly better than before the testing. This shows that the experimental groups' vestibular function, excluding visual and physical senses, is improved after the experiment as shown in [Table 3]. These results quantitatively prove that the Wii exercise program, a practical and simple virtual reality exercise program, has the effect of improving the vestibular function of the patients.

In general, normal people rely mainly on their own visual information to maintain balance. However, in condition 6, when misinformation is received, such as confusion of vision, the dependence on the vision is suppressed and the dependence on the information obtained from somatosensory or vestibular sensation becomes more dependent to correct the posture. Therefore, the improvement in condition 6 after treatment meant that the central nervous system of the experimental group improved the ability to select correct information from vision. It was argued that training by giving immediate visual feedback could improve balance. This is because it is possible to reinforce motor relearning of nerve rehabilitation using mirror nerve cells by observing one's own motion while performing the motion. From this, it can be concluded that the scores of condition 6 improved because the patients in the experimental group were trained with a game machine with rich visual feedback.

Another aspect of the improved score of the VST in sensory analysis showed that the exercise program has improved the supervisory control ability of the cerebellum to the vestibular system. From a neurophysiological point of view, the cerebellum plays a major role in learning to control and supervise feedbacks for postural control, and the basal ganglia is important for maximizing rewards in feedbacks. The cerebellum is an important backbone of integrating various sensory information such as visual vestibular sensation and somatic sensation to implement vestibular spinal reflex that corrects posture. Patients would have been trained to improve their ability to integrate visual and vestibular information as much as possible, as the cerebellum received a lot of feedback of visual and vestibular senses while exercising in virtual reality.

In addition, the virtual reality exercise program provides a rich environment for sensory signals that combine visual, hearing, and proprioceptive sensory feedbacks, so subjects can see their equilibrium and gesture conditions directly and receive visual and hearing feedbacks to enhance stimuli from the vestibular system and stimuli of the high-level receptor while performing exercises presented in virtual reality. It is thought to have improved the body's ability to balance itself by exerting more attention and concentration on the mobility needed in the game and utilizing the muscular kinematic, eye-splitting, cerebellar, and limbic circuits.

Recalling that the improvement of the patient's balance ability is significant for inhibiting falls and improving the QOL, it can be concluded that, as demonstrated in the improvement of the patient's

dynamic posturography test results in this study, physical activity through virtual reality can bring about an improvement in balance ability and can improve the quality of life.

The findings are consistent with a recent study report on the effectiveness of virtual reality exercise programs in patients with equilibrium disorders. A virtual reality exercise therapy was effective in improving the QOL of 20 patients with degenerative brain diseases through playing Wii games three times per week about four weeks. The tendency to improve their physical activity, enhance motor skills, and lessen depression than before the program were observed[15].

The experiments which applied Wii exercise programs to patients with Parkinson's disease for eight weeks showed statistically significant differences than before through the Berg balancing and functional stretching tests, one-leg-stand-up tests, wake-up-and-go tests, and lower leg muscle power tests after training[16]. However, this was not a quantitative test using a dynamic posture meter because it used a subjective scale. In addition to Wii, there are other home game consoles with virtual reality, such as Xbox Kinect, PlayStation VR, and Oculus VR. However, there have been no reports so far that they have been used to alleviate the likelihood of falls among elderly people living alone.

A few studies conducted in South Korea applied Wii on dementia patients admitted at a facility or hospital two to three times per week for a whole of six weeks. The results showed a significant improvement in their depressive symptoms, cognitive function, and daily activities after the experiment. However, the subjects had not been categorized based on risk of fall, so it was difficult to determine the therapeutic effects according to the level of balancing abilities[17]. In the present study, the experimental group showed improvement in depressive mood. The result that made patients enjoy and satisfy with the treatment were reflected in the fact that 58% of them wished to continue treatment after the study.

The influences of the Wii for the lonely living elderly may have caused due to the steady stays and social transactions with the partners had a helpful effects upon the socio-psychological aspects of the patients who had been separated from society. After the program, the applicants knew better social support[18].

The progress in equilibrium ability and depression in investigational group could be because of the socio-emotional advantages that the game-type virtual reality exercise program gave the patients[19]. First, the patients increase their concentration through the consoles. Second, patients who are immersed in sports are more competitive and motivated to score better points based on the results of the game, so by activating the reward circuitry, more symptoms can be improved by placebo effect. Third, playing games can relieve stress and anxiety. In this study, 53% of patients wanted to continue exercise with the Wii system after the program. This was similar to a prior study report, that 60% of the subjects wanted to purchase Wii for home use after eight weeks of exercise[20]. Regarding the effects of Wii on stress and anxiety of the patients, the program seemed to be also effective in minimizing the boredom for subjects who experienced stress and lost interest in a long-term rehabilitation treatment. It can be concluded that a VR-game-based intervention helped reduce the stress in performing a task,

There were several limitations to this study. First, the problem with this study is that the number of experimental groups was not large enough. The number of paients in the investigational group was not big enough to put results onto the entire elderly people with cognitive deterioration. The number of subjects in the investigational group was not great enough to put results onto the whole elderly people with cognitive decay. The second, the test time was rather brief. Finally, considering the fact that this test had the observational features, it could not be possible to control the doings made outside of controlled sessions, including exercise. Therefore, participants could increase their level of activity as their bodily act and anxiety of falling amended, resulting in additional buildups after intervention. Finally it raised a question whether other home game consoles such as Xbox Kinect, PlayStation VR, and Oculus VR can be used for treatment.

As a strong point of this study, a novel, accessible technique definitely intended to heal balance in the elderly populace living alone with a high jeopardy of falls was tested. Furthermore, there have been few

studies which provide extensive quantification of the balancing performance that was applied in this study to comprehend the influence of VR on risk of fall. The aims of the study, targeting to quantitatively examine the improving outcome of VR exercise program made up on Wii on balance functions within the subjects using the computerized dynamic posturography, was successfully met.

The Wii program, which does not take up much space, is inexpensive, easy to move and install, motivates patients' interests, and can be widely applied to physical therapy for elderly patients who lives alone and with high risk of falling. With the stated limitations on the study, further research is needed. A suggestion to future study will be to investigate whether other home game consoles such as Xbox Kinect, PlayStation VR, and Oculus VR could show the same results as to be recommended for treatment.

5. Conclusions

This study aimed to define the effect of virtual reality programs made up of Wii sports game on the balance of elderly people, living alone and falling frequently, through quantitative measuring. The investigational group led three sessions of Wii balance exercises for 40-minute per week for total 12 weeks. Computerized dynamic posturography was used to evaluate as a quantitative measuring of the subjects' balance ability. After 36 training sessions, sensory organization test showed significant differences in conditions 5 and 6, and furthermore, vestibular ratio within the investigational group from beginning to end of experiment. This study demonstrated quantitatively that virtual reality exercise programs made up of Wii can improve the balancing ability of the elderlies living alone who fall frequently.

References

[1] R. Patil, K. Uusi-Rasi, P. Kannus, S. Karinkanta, H. Sievanen, Concern about falling in older women with a history of falls: associations with health, functional ability, physical activity and quality of life, Gerontology, (2014), Vol.60, No.1, pp.22-30, https://doi.org/10.1159/000354335

[2] A. Morrison, T. Fan, S. S. Sen, L. Weisenfluh, Epidemiology of falls and osteoporotic fractures: a systematic review, Clinico Economics and Outcomes Research, (2013), Vol.5, pp.9-18, https://doi.org/10.2147/CEOR.S38721

[3] J. M. Furman, Y. Raz, S. L. Whitney, Geriatric vestibulopathy assessment and management, Current Opinions of Otolaryngology and Head Neck Surgery, (2010), Vol.18, No.5, pp.386-391, doi: 10.1097/MOO.0b013e32833ce5a6

[4] M. Lee, A Study on the care experience of the elderly with dementia and the quality of life of the family, Asia-pacific Journal of Convergent Research Interchange, (2018), Vol.4, No.1, pp.53-61.

[5] G. S. Park, H. Y. Jeong, S. N. So, Y. H. Park, H. J. Yang, G. R. Jung, S. J. Moon, H. Y. Kim, J. H. Cho, K. H. Yang, The effects of the activity program for preventing dementia against depression, cognitive function, and quality of life for the elderly, The Korean Society of Oriental Neuropsychiatry, (2013), Vol.24, No.4, pp.353-362, UCI : G704-001485.2013.24.4.002

[6] E. Lee, Who are those happy elderly people?, Asia-pacific Journal of Convergent Research Interchange, (2018), Vol.4, No.2, pp.43-50.

[7] B. Nadella, Eyes Detection and tracking and eye gaze estimation, Asia-pacific Journal of Convergent Research Interchange, (2015), Vol.1, No.2, pp.25-41.

[8] Jungjin Kim, Ku Seul, Lee Jinju, Kim Yusin, Bum-Chul Yoon, The effects of virtual reality-based continuous slow exercise on factors for falls in the elderly. The Journal of Korean Society of Physical Therapy, (2012), Vol.24, No.2, pp.90-97, UCI : G704-SER000001656.2012.24.2.012

[9] Ross A. Clark, Adam L. Bryant, Yonghao Pua, Paul McCrory, Kim Bennell, Michael Hunt, Validity and reliability of

the Nintendo Wii Balance Board for assessment of standing balance, Gait Posture, (2010), Vol.31, pp.307-310.

[10] Donggyu Lee, EunKyung Kim, Yongnam Kim, Yongseong Kim, TaeYeon hwang, Effects of a virtual reality training program on balance and lower muscular strength of Parkinson's disease patients, The Journal of Korean Society of Physical Therapy, (2013), Vol.25, No.2, pp.96-102, UCI : G704-SER000001656.2013.25.2.003

[11] F. Lundin, T. Ledin, C. Wikkelsø, G. Leijon, Postural function in idiopathic normal pressure hydrocephalus before and after shunt surgery: A controlled study using computerized dynamic posturography (EquiTest), Clinical Neurology & Neurosurgery, (2013), Vol.115, No.9, pp.1626-1631, https://doi.org/10.1016/j.clineuro.2013.02.015

[12] S. Phu, S. Vogrin, A. Al-Saedi, G. Duque, Balance training using virtual reality improves balance and physical performance in older adults at high risk of falls, Clinical Interventions in Aging, (2019), Vol.14, 1567-1577, doi: 10.2147/CIA.S220890

[13] D. Rand, W. C. Miller, J. Yiu, J. J. Eng, Interventions for addressing low balance confidence in older adults: a systematic review and meta-analysis, Age Ageing, (2011), Vol.40, No.3, pp.297-306, DOI: 10.1093/ageing/afr037

[14] J. W. Yoon, B. S. Oh, T. S. Kim, Effect of 8 weeks Nintendo Wii fit/sports exercise on body composition and object control function in male high school student with intellectual disability, Journal of Sport and Leisure Studies, (2011), No.46, pp.1099-1108, DOI : 10.51979/KSSLS.2011.11.46.1099

[15] N. B. Herz, S. H. Mehta, K. D. Sethi, P. Jackson, P. Hall, J. C. Morgan,, Nintendo Wii rehabilitation ("Wii-hab") provides benefits in Parkinson's disease, Parkinsonism and Related Disorders, (2013), Vol.19, No.11, pp.1039-1042, DOI: 10.1016/j.parkreldis.2013.07.014

[16] J. F. Esculier, J. Vaudrin, P. Beriault. K. Gagnon, L. E. Tremblay, Home-based balance training programme using Wii fit with balance board for Parkinson's disease: a pilot study, Journal of Rehabilitation Medicine, (2012), Vol.44, No.2, pp.144-150, DOI: 10.2340/16501977-0922

[17] H. M. Sim, P. Ishvi, Analysis of an Axial T2 Weighted Brain MRI, Asia-pacific Journal of Convergent Research Interchange, (2017), Vol.3, No.1, pp.45-55.

[18] K. W. Cho, S. C. Choe, The Effect of the elderly's motivation to participate in lifelong education on their Life Satisfaction, Asia-pacific Journal of Convergent Research Interchange, (2019), Vol.5, No.2, pp.59-67.

[19] T. Kim, A Study on physical protection requirements for game-based learning (GBL) management system, Asia-pacific Journal of Convergent Research Interchange, (2018), Vol.4, No.1, pp.41-51.

[20] J. H, Lee, S. U. Park, J. I. Kang, D. J. Yang, S. K. Park, Effects of virtual reality exercise program on muscle activity and balance abilities in elderly women, The Journal of Korean Physical Therapy, (2011), Vol.23, No.4, pp.37-44, UCI : G704-SER000001656.2011.23.4.002