



Original Article

## Improvement in the physiological function and standing stability based on kinect multimedia for older people

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**Abstract.** [Purpose] The increase in the Taiwanese older population is associated with age-related inconveniences. Finding adequate and simple physical activities to help the older people maintaining their physiological function and preventing them from falls has become an urgent social issue. [Subjects and Methods] This study aimed to design a virtual exercise training game suitable for Taiwanese older people. This system will allow for the maintenance of the physiological function and standing stability through physical exercise, while using a virtual reality game. The participants can easily exercise in a carefree, interactive environment. This study will use Kinect for Windows for physical movement detection and Unity software for virtual world development. [Results] Group A and B subjects were involved in the exercise training method of Kinect interactive multimedia for 12 weeks. The results showed that the functional reach test and the unipedal stance test improved significantly. [Conclusion] The physiological function and standing stability of the group A subjects were examined at six weeks post training. The results showed that these parameters remained constant. This proved that the proposed system provide substantial support toward the preservation of the Taiwanese older people' physiological function and standing stability.

**Key words:** Balance, Interactive, Multimedia

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### INTRODUCTION

Taiwan, as noted by the United Nations (UN), has become a developed country with an aging population. Falls are the main cause for injury and death in the older people (> 65 years)<sup>1, 2)</sup>. According to the statistics, during 1986–2007, 26,793 people fell down in Taiwan. About 33–50% of the older people over 65 years have fallen down before<sup>3, 4)</sup>. Several systematic reviews and meta-analyses present powerful evidence to support the role of the physical exercise in preventing the older people from falls. In Taiwan, common physical exercise training includes walking, biking, aerobics, balance and muscular endurance training, resistance training<sup>5)</sup>, Tai Chi<sup>6)</sup>, etc. The goal is to improve the older people's standing stability, thereby reducing the rate of falls<sup>7–10)</sup>. However, these methods do not include the effective training of the physical sensory integration. Furthermore, they cannot provide substantial training for the maintenance of the physiological function and standing stability for the older people who dislike going out.

There have been a few studies on the use of the virtual reality and Kinect technology in this direction<sup>11–15)</sup>. The present study involved the use of Kinect technology to develop an interactive multimedia exercise training system suitable for the older people in Taiwan. When using this technology the user does not need to put on any device. Through a virtual goalkeeper, the older people can play soccer by only using their limbs. During the training each part of their body, including the eyes, hands, feet, and torso can be coordinated. In addition, their physiological function and standing stability can be improved or maintained.

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This system has been proved highly reliable and effective in improving the older people's standing ability. The unipedal stance test (UST), the Functional Reach Test (FRT), and the Four Square Step Test (FSST) were used for the assessment of the system's validity<sup>16-18</sup>.

## SUBJECTS AND METHODS

Figure 1 illustrates the entire system constructed during this study. By retrieving signals from the older people's bodily movement and constructing a virtual soccer pitch scenario using interactive multimedia, the participant can serve as the goalkeeper in the screen. The participant will (1) follow the ball kicked out in the screen, (2) raise a limb to tackle the ball (e.g., the right hand indicated in the figure), (3) Kinect technology will retrieve the coordinates from the limb images during the movement, and (4) record in real time the subject's posture and number of tackles. The game levels will be adjusted according to the participant's performance. The participant's coordination of his/her upper and lower limbs can gradually be improved. A record of the participant's performance is registered automatically by the system to serve as the reference for the exercise analysis and construction of medical evaluation methods.

Using the sagittal and horizontal planes, the participant's body is divided into the left and right part, and the upper, middle, and lower part. There are six areas as indicated in Fig. 2. The ball will be evenly distributed to these six areas. The participant will use the corresponding limbs to tackle the ball. The game has 10 levels of increasing difficulty, and the participant will start from level zero (beginners). If the participant tackles more than 80% of the balls, he/she can move on to the next level. This game is design to benefit for the older people, allowing them to avail of the most suitable and effective exercise training.

Figure 3 illustrates the time relationship between the intervals, that is, when the ball is served and hit, and the moment the ball is hit between two consecutive levels. The interval relationship between the time when the ball is served and when the participant hits the ball is  $T_{j, \text{waiting interval}}$  to  $T_{j, \text{appear}}$ . During the entire training period, the above-mentioned process is continuously repeating. The participant has to hit the ball during  $T_{j, \text{appear}}$ . If the participant hits the ball correctly, the ball will disappear from the screen, and the game will immediately move on to the waiting interval for the next ball. The faster the participant can hit the ball, the more chances he/she has for the ball to be served and tackled during the training exercise.

At the starting level (level 0), the interval between each ball is of 5 seconds (default value). The waiting interval ( $T_{j, \text{waiting interval}}$ ) between the time the ball is hit and the next ball is served in level  $j$  and its relation with  $T_0$  is  $T_0 \times (1 - 0.05 \times j)$ . This is expressed in seconds.

This study included healthy older people aged > 65 who were able to walk independently. Patients with neurological diseases, such as Parkinson's disease, Alzheimer's disease, stroke, etc., and a mini mental state examination (MMSE) > 27, or having difficulties walking due to arthritis, visual impairment, and cardiovascular disease were excluded from this study. Figure 4 evidences the screening process for the subjects. From 48 older people that volunteered for this study, five were excluded. The remaining 43 participants (19 recruited during community medical services; 24 from the outpatient rehabilitation service) were divided before the initial assessment into group A (21 subjects, aged between 65 and 73 years) and group B (22 subjects, aged between 65 and 76 years). One of the subjects in group A failed to complete the whole training because of traffic related consideration, while two in group B could not complete the whole training because of personal or medical considerations. Table 1 presents the subjects data.

The study was conducted over a period of 12 weeks. In the first six weeks, group A did the multimedia training exercises and group B did the free exercises for the arms and legs; both groups exercised twice a week, for 30 minutes at a time at the most. Starting with week 7, the groups swapped the type of exercise; thus, group A performed the free exercises for the arms

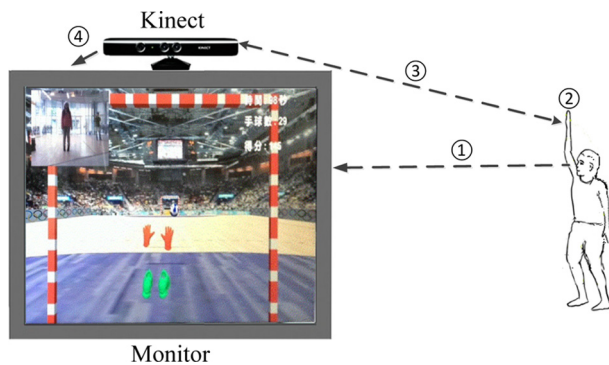


Fig. 1. The interactive multimedia exercise training system

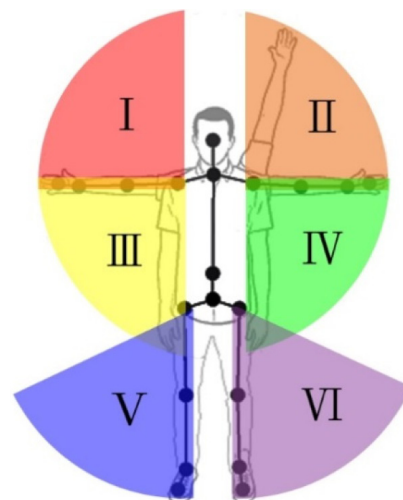


Fig. 2. The six areas where the ball is served

and legs, and group B performed the multimedia training exercises. The schedule for the exercises was the same for all the 12 weeks. During the entire exercise period, depending on the subject's ability, the training started from the level of "slow" ball. After the subject passed the basic training level and the medical staff confirmed that was safe for him/her to continue, he/she moved on to a higher level. The subject had to tackle the ball according to the direction it was virtually served. Automatically, for each session the system recorded the number of times the ball was successfully hit, the scores, the movement of the limbs, etc. The entire period spent for the evaluation was divided into the one before the first week (pretest), the end of the week 6 (middle test), and the end of the week 12 (post-test). The evaluation indicators were FRT, UST, FSST, and measure of the physiological parameters, such as blood pressure, heartbeat, and SPO<sub>2</sub>. The training procedure is presented in Fig. 5.

The following is a description of the relevant evaluation indicators, based on the three scales were used when conducting

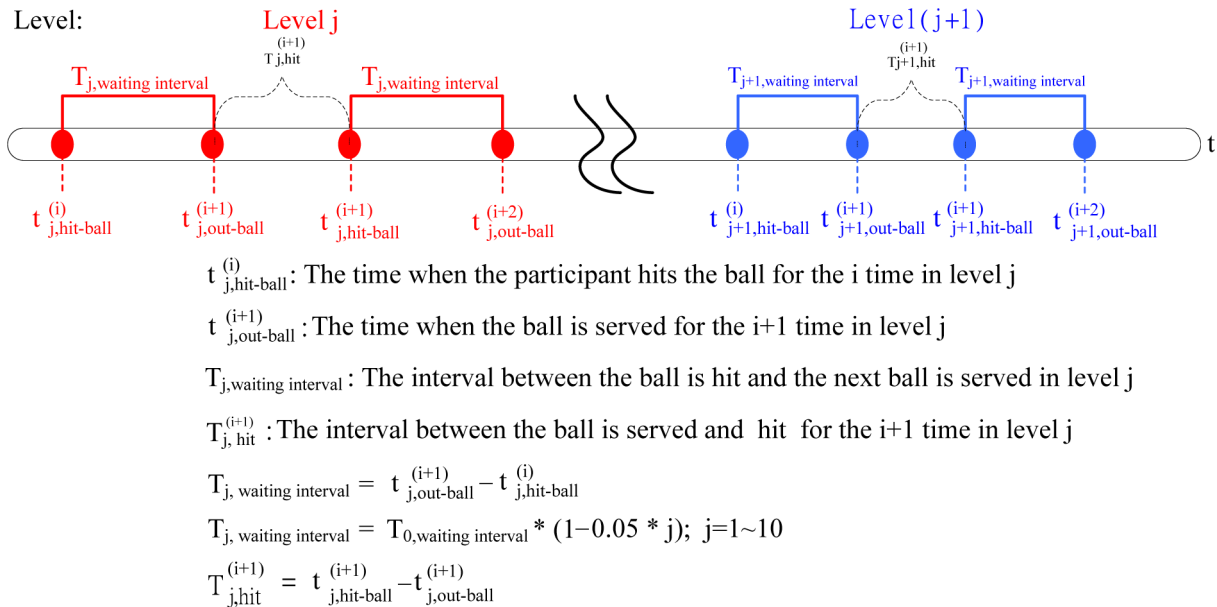


Fig. 3. The time relationship between two adjacent levels of the game

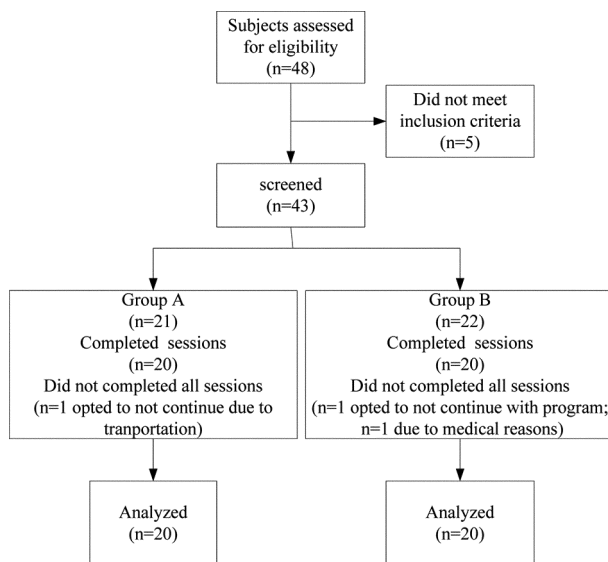


Fig. 4. The screening process for the participants

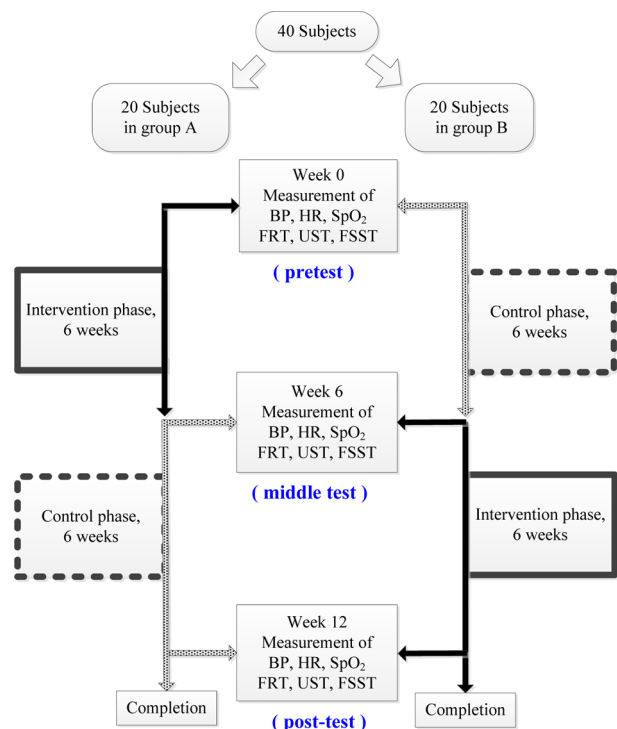


Fig. 5. The training procedure scheme

the tests.

(1) FRT: Evaluates the subject's dynamic balance ability. Measures the subject's distance of the maximal horizontal forward movement, when the subject is within the range of an unmovable surface.

(2) UST: Evaluates the subject's static balance ability. Measures the subject's visual perception balance while standing on one foot with the eyes opened. Furthermore, it measures the subject's proprioception of balance while standing on one foot with the eyes closed. This test is an important indicator that predicts the potential for injury during the fall down inconvenience.

(3) FSST: Evaluates the subject's dynamic balance ability. The subject's capability of negotiating over one object while moving forward, rightward, leftward and backward.

The above-mentioned evaluation indicators require the subject to practice once before taking the test. Further, the test is given twice and the best result is recorded.

To study the subjects' physical condition during training, their physiological signals (e.g., blood pressure, heartbeat, and SPO<sub>2</sub>) were measured during all the three time points (pretest, middle test, post-test). The data were statistically analyzed using the SPSS software.

The study was approved by the Ethical Committee of the Taipei Medical University Hospital, and a written informed consent was obtained from each participant.

## RESULTS

The reference values for the physiological signals were: (a) normal value of the systolic blood pressure (SBP) / diastolic blood pressure (DBP) between 100–140 / 66–90 mmHg; (b) heartbeat 65–80 bpm; (c) SPO<sub>2</sub> no less than 96%. Table 2 shows the average values for all the participants' physiological signals for the three periods. When comparing the values taken from the group A participants, the average SBP/DBP decreased slightly (122/77 mmHg > 123/75 mmHg > 117/77 mmHg). The average heartbeat value had slightly dropped (76 bpm > 80 bpm > 78 bpm). The SPO<sub>2</sub> was constant (about 98%). When comparing the values recorded for the group B participants, SBP/DBP decreased from 132/73 mmHg to 129/75 mmHg, and again to 128/69 mmHg. The average heartbeat value slightly decreased from 79 bpm to 77 bpm, and again to 75 bpm. The SPO<sub>2</sub> was constant remained the same (about 98%). There was no statistical difference when comparing the physiological signal results between the two groups (p>0.05). This indicates that the 12 week exercise training proved successful maintaining the physiological functions of the older people.

The evaluation of the risk for falls included the FRT, UST, and FSST measurement. All the results are presented in Table 3 and illustrated as follows:

(1) FRT: When comparing the data for group A with those for group B, the pretest value (Fig. 5) was 35.5 cm and the

**Table 1.** The participants' data

	Group A (age: 65–73)	Group B (age: 65–76)
Number of participants	20	20
Age (years)	69.7± 2.7	71.2 ± 4.3
Gender		
Male	10	9
Female	10	11
Personal condition:		
Height (cm)	161.7 ± 5.9	156.4 ± 4.4
Weight (kg)	60.5 ± 7.6	57.0 ± 8.4
BMI (kg/m <sup>2</sup> )	23.2 ± 3.0	23.2 ± 2.7
MMSE	>27	>27

**Table 2.** The average values of the physiological signals

Physiological signals	Group A	Group B
Systolic blood pressure (mmhg)	122/123/117*	132/129/128
Diastolic blood pressure (mmhg)	77 /75 /77	73 /75 /69
Heart rate (bpm)	76 /80 /78	79 /77 /75
SPO <sub>2</sub> (%)	98 /98 /98	98 /98 /98

\*means that the numbers 122/123/117 are the averages in the baseline/6th week/12th week of the training program, respectively

value for the middle test was 30.2 cm (Fig. 5). Furthermore, the middle test value is 46.4 cm compared to 39.3 cm for the post-test (Fig. 5). These results were significantly different, indicating that the game was helpful in improving the FRT for all the participants. The middle test and post-test values in group A are 46.4 cm and 45.9 cm, respectively. There was only a slight variation between the two values, suggesting that this game is functional for the FRT maintenance of the older people.

(2) UST: When comparing the two groups' data, the pretest of group A is 43.2 sec as opposed to 35.2 sec for the middle test. Furthermore, the middle test value is 55.7 sec compared to 41.9 sec (post-test) (Fig. 5). The results showed significant differences, confirming that group A performs better than group B. The group's A post-test result was higher when compared to the middle test results (58.3 sec versus 55.7 sec), This indicated that the game is functional for UST maintenance of the older people.

(3) FSST: The values for the three measurements in both groups were close enough, suggesting that the game was not significantly effective for the subjects' FSST. This means the game is not very helpful for improving the older people' FSST.

Table 3 illustrates the FRT, UST, and FSST statistical data for pre-test/middle test, pre-test/post-test, and middle test/post-test. There were significant differences when comparing both groups' FRT and UST between the pretest and middle test (group A), and middle test and post-test (group B), respectively (FRT's  $p < 0.01$ ; UST's  $p < 0.05$ ). However, the FSST results between these tests in both groups were not significantly different ( $p > 0.05$ ).

## DISCUSSION

The system developed in this study can automatically register the participant's leveling up conditions, and the number of tackled balls. According to the run chart presented when conducting the statistical analysis, both groups are able to maintain a constant physiological function. Furthermore, their FRT and UST improved significantly following training. According to data of group A, the subjects' results improved during the pre-test and middle test, and were able to preserve the training's effects by only performing regular activities and without exercising a period of 7 to 12 weeks. Therefore, the older people should exercise at regular time intervals. This will benefit to preserve their physiological condition and prevent them from falls.

The entire study's evaluation includes the measurement of the physiological signals (blood pressure, heartbeat, and  $SPO_2$ ) and the assessment of the fall down risks (FRT, UST, and FSST) in terms of pretest, middle test and post-test periods. The results from both groups' physiological signals were constant. The fall down risk assessment evidenced that the FRT and UST improved significantly, while FSST showed no significant difference for all the three periods. The later result might be attributed to the difficulty encountered when performing the movements necessary for the FSST evaluation. FSST requires the subjects to move their body, change directions and remember a series of postures, etc., which proves more difficult for the older people.

This study proposed a virtual training activity combining a somato-sensorial system, interaction, games, and other techniques without requiring the use of any wearable devices. Under the therapist guidance, the participants can easily learn how to operate this simple training system by themselves. The device hardware is not expensive, which makes it affordable for participants to exercise at home. Effectively, this system saves energy and time when considering the transportation means. In particular, for those older people who do not enjoy outdoor activities, it is a simple and affordable training alternative. This device helps to maintain the older people's physiological function and stability. In addition, the subject's data can be uploaded to the cloud through the Internet, so that the doctor can monitor the subject's physical condition on a long-term basis.

**Table 3.** The evaluation of the overall risk of falls and standing stability

	FRT (cm)		UST (sec)		FSST (sec)	
	Group A	Group B	Group A	Group B	Group A	Group B
Pre-study	35.5±5.8 *	29.6±3.7	43.2±13.9 *	34.4±18.7	9.6±2.2	10.2±1.5
Week-6	46.4±7.5	30.2±2.6	55.7±12.9	35.2±19.1	9.2±2.7	9.9±1.7
Pre-study	35.5±5.8 *	29.6±3.7 *	43.2±13.9 *	34.4±18.7 **	9.6±2.2	10.2±1.5
Week-12	45.9±7.2	39.3±5.3	58.3±5.2	41.9±13.8	9.2±2.5	9.9±2.4
Week-6	46.4±7.5	30.2±2.6 *	55.7±12.9	35.2±19.1 **	9.2±2.7	9.9±1.7
Week-12	45.9±7.2	39.3±5.3	58.3±5.2	41.9±13.8	9.2±2.5	9.9±2.4

\* $p < 0.01$ ; \*\* $p < 0.05$

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