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ORIGINAL

The Development of Rhythmic Balance Training Equipment and its Effect on Performance for Elderly

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Objective: The aims of this study were 1) to develop easy-to-use rhythmic balance training equipment for the elderly and 2) to investigate the effect of training with the equipment on balance and physical function.

Method: Twenty-one elderly individuals (age: 75.4±3.34 yrs, height: 152.07±4.81 cm, weight: 58.35±8.34 kg) participated in this study. Each participant underwent balance and physical function testing before and after 12 weeks of training with the equipment. Y-balance (i.e. dynamic balance) and one leg static balance tests were used for balance testing, and timed up- and-down-stairs and five times sit-to-stand tests were used for physical function testing. A paired *t* test was used to determine whether there was a significant pre- and post-training difference.

Results: The rhythmic balance training equipment provided a fun and motivating training program with age-friendly music, dance movements for lower extremity strength training, and touch screen controls with simple features. Post-training left foot dynamic balance was significantly greater ($p<.05$), and static balance with eyes open was significantly improved ($p<.05$) compared to pre-training. Completion of the timed up-and-down-stairs and the five times sit-to-stand tests was significantly shorter ($p<.05$) compared to pre-training.

Conclusion: Training using the equipment developed in this study improved balance and physical function in elderly participants.

Keywords: Elderly, Balance training equipment, Rhythmic, Balance test, Physical function

INTRODUCTION

The elderly accounted for 13.1% of the entire population of Korea in 2015, with 6,624,000 individuals, and are projected to account for 40% of the total population in 2060. The drastic increase in medical expenses for the elderly (3,220,000 Won per person in 2014) is becoming a social problem (StatisticsKorea, 2015). From a social welfare point of view, the idea of disseminating various types of exercise equipment to reduce medical expenses for the elderly is spreading (Josephs, Pratt, Meadows, Thurmond, & Wagner, 2016).

Exercise training programs for the elderly have evolved in different ways. Korean exercise training programs such as Pilates (Kim, Rhyu, & Hong, 2011; Kang & Jon, 2014), walking (Choi & Lee, 2013; Kim & Beak, 2016), and step box (Kim, Choi, & Kim, 2016) have been used to promote exercise among the elderly. Internationally, training programs using dance (Kattenstroth, Kolankowska, Kalisch, & Dinse, 2010; Rahal et al., 2015), resistance bands (Wessner, 2016; Nemček & Simon, 2016; Oh et al., 2016), square-stepping exercise (Teixeira et al., 2013_ENREF_17; Jindo et al., 2016), and resistance with dumbbells, barbells, or cable have been recently used among the elderly (Peltonen, Arokoski, Kallinen, & Pullinen, 2012). A 2013 study by Jorgensen, Laessoe, Hendriksen, Nielsen, & Aagaard reported that most training programs for the elderly are composed of simple exercises, and more entertaining programs are needed to replace monotonous exercise programs. Park, Kim, Kim, Lee & Lim in 2010 also emphasized the need for development of an exercise program for the elderly with music and choreography to maintain interest.

Nintendo's *Wii Fit* (Jorgensen et al., 2013), which was developed in Japan, maintains the user's interest by providing numerous programs such as yoga, strength and cardiovascular exercise training, and balance games. Because *Wii Fit* is a program in which the user simply repeats the motion shown on the screen, it is debatable whether *Wii Fit* can effectively provide exercise training with only the user's weight and strength.

Only a few pieces of exercise equipment designed for the elderly are used in Korea and overseas. As several previous studies show, exercise training for the elderly has mostly been conducted using tools (tilting boards, foam plates, dumbbells, and resistance training machines) rather than equipment (Gillespie et al., 2009; Patil et al., 2015). Many pieces of exercise equipment have been developed for the elderly with a focus on rehabilitation, however. In Japan, water resistance equipment has been developed in which the user wears sock-like devices and walks forward in water to increase lower limb strength and balance (Katsura

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et al., 2010). Equipment developed by Jung, Chun, Hong & Lim in 2015 induces lower limb joint movement (hip, knee, and ankle joints) while the user stands on a board capable of dynamic rotations in four directions (anterior-posterior, right-diagonal, medial-lateral and left-diagonal); this equipment was originally developed to rehabilitate dynamic balance in the elderly.

Although these exercise programs were designed for rehabilitation, the creators did not consider motivation to participate in exercise. Elderly individuals cannot operate the exercise equipment by themselves, and their participation and entertainment were not taken into account.

In this study, a number of factors that promote effective exercise programs and equipment were identified. We addressed the need for exercise equipment that can be operated by the elderly, and exercise programs that maintain interest for self-motivation. To develop an exercise that improves lower limb strength and balance, we encouraged full weight movement synchronized with music, measured by load cells in the stepping mat. This training method improves balance in the elderly by inducing different ankle movements (flexion, extension, inversion, eversion, and rotation) depending on the shape of the stepping mat.

The purpose of this study was to develop balance-training equipment that can be self-operated by the elderly while maintaining the user's interest. The results of a 12-week training program were used to confirm the effectiveness of the exercise equipment developed in this study.

METHODS

The motivation and sentiment of the Korean elderly were taken into account to develop the exercise equipment. The equipment is a rhythmic step workout machine that adapted flexion movements of Korean traditional dance, and was developed to increase balance and cardiovascular fitness in the elderly. The equipment components include hardware (Patent application No.10-2014-0032652) and software (Patent application No. 10-1624032) (Park, 2014a, 2014b).

1. Development and characteristics of rhythmic balance training equipment for the elderly

1) Hardware design

As shown in (Figure 1), the hardware is composed of a ball plate that

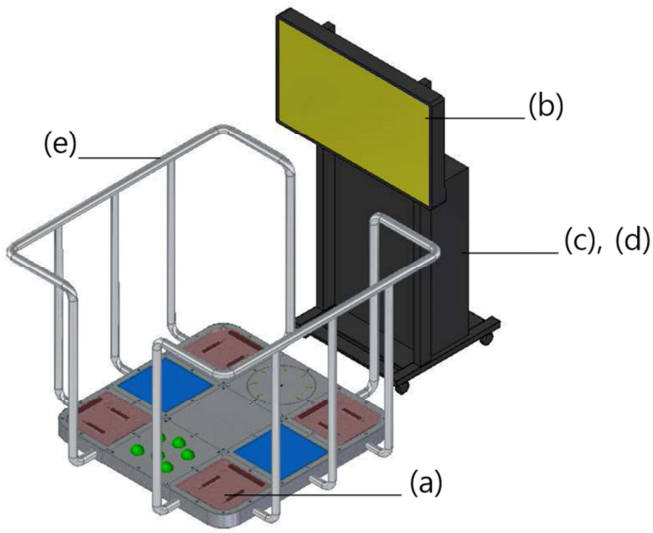

Figure 1. Hardware design for the rhythmic balance training equipment. Eight panel plates (a), touch screen monitor (b), computer (c), power switch (d), and frame for safety (e).

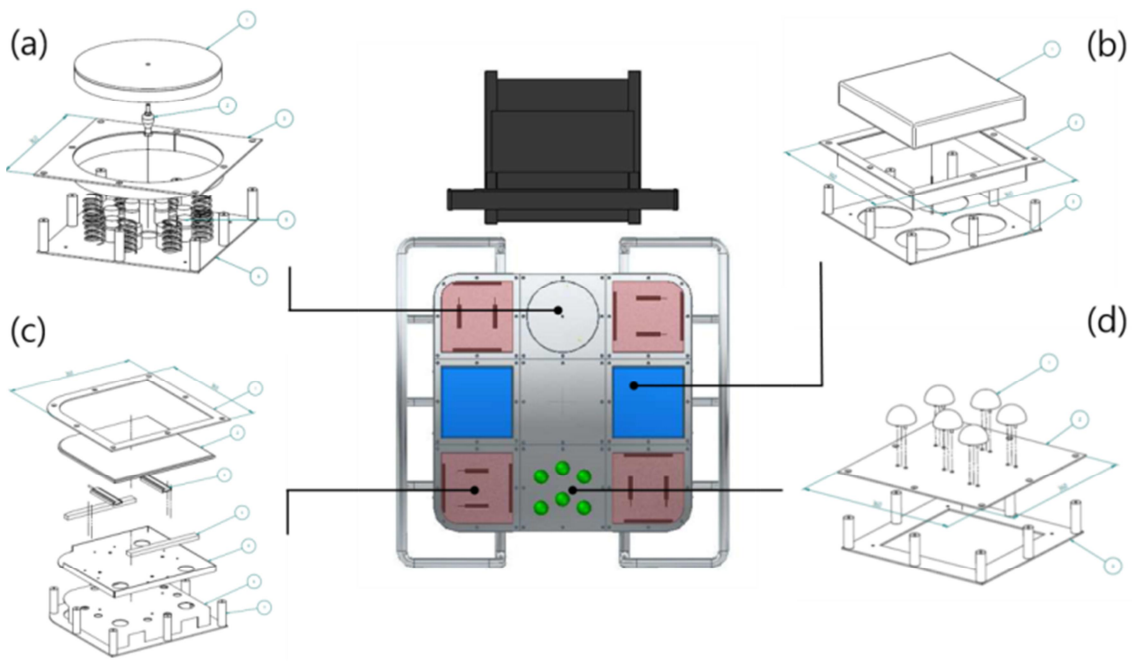

Figure 2. Detailed assembly drawings of panel plate. Rotation plate for circumduction (a), balance -pad plate (b), flat plate of light guide panel (c), and ball plate panel (d).

Table 1. Hardware composition

Name	Compositions
Panel plate	2 flat panels (included pressure sensor), 1 rotation plate panel, 1 ball panel, 2 balance-pad panels.
Frame for safety	Handle base frame connected pane base frame
Touch screen monitor	32" LCD Touch screen monitor
Computer	CPU: core 4, i3-4130(3.4GHz), Mainboard: ASUS B85M-G STCOM, Memory: Samsung DDR3 4GB PCI3-12800, HDD: Samsung 120Gb, Power: ATX500W, Case: minitower, OS: Win7 Pro
Power switch	Selector switch with control, CR-243-1, rated current -5A-250V AC
PC switch	Push button switch, F16, rated current -DC12V 3A

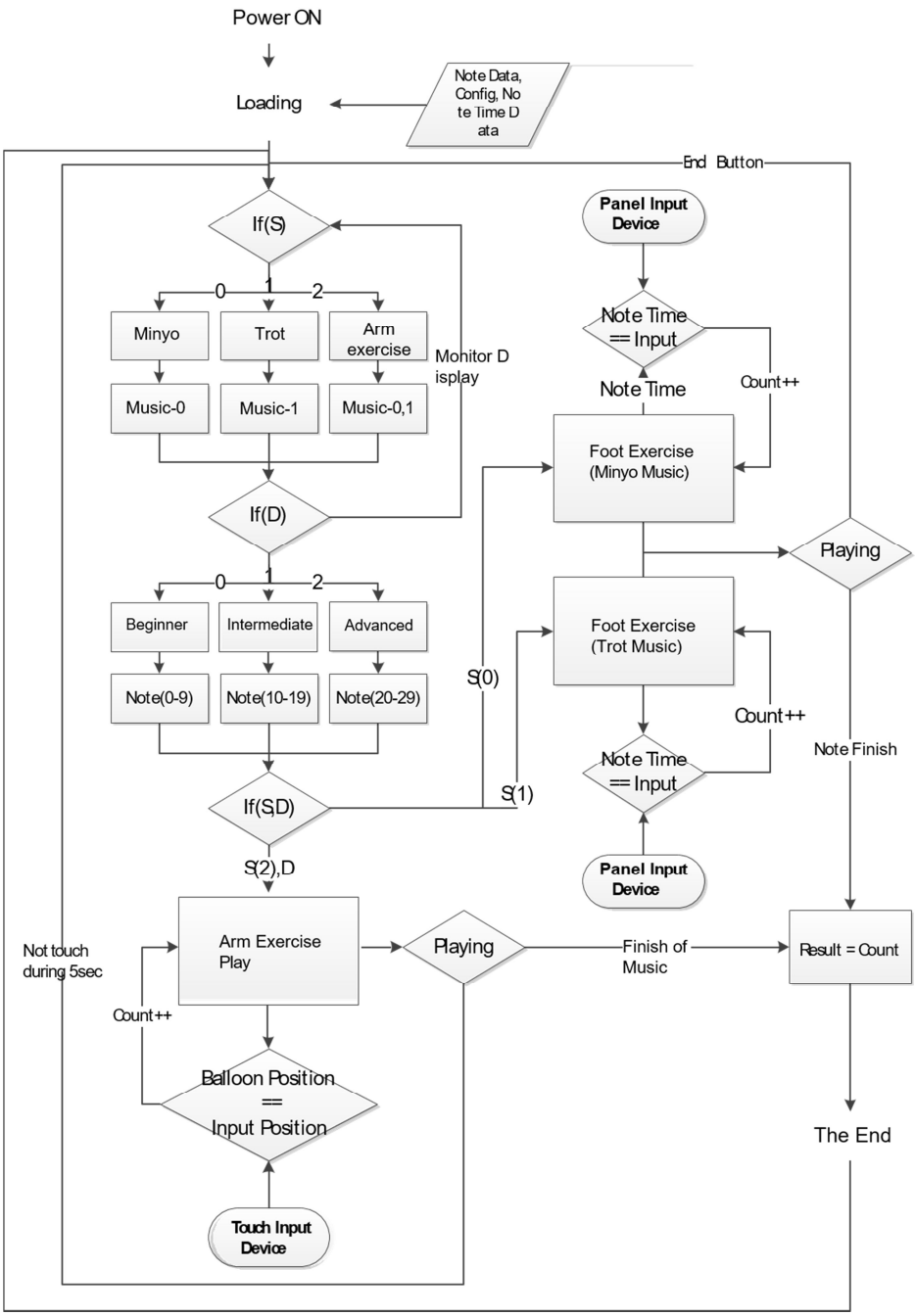

Figure 3. Software flow chart.

induces ankle flexion, extension, and rotation, and a balance plate that induces ankle eversion and inversion. The main footboard is composed of eight ground panels (Figure 2), computer, monitor, safety frame, and power switch.

2) Hardware composition

The hardware composition is shown in (Table 1).

3) Software flow chart

As shown in (Figure 3), the software is in Korean. The music is selected randomly and played when either leg or arm exercise is selected. The program can be exited at any point, and feedback is provided upon completion of a song (Figure 3).

4) Display

The components of the display are shown in (Figure 4).

In the genre-selecting display (a), the user can select songs and lower limb or upper limb exercise. The exercise program starts when the difficulty (beginner, intermediate, and advanced) is selected on the display (b-1) and (b-2). Lower limb exercise is conducted by stepping on the step mat as indicated by the display in lower limb exercise play mode (c-2). There is an exit button, which allows the user to go back to the main menu at any point. In the balloon popping display (c-1), which is the upper limb exercise mode, the balloons displayed on the monitor have to be popped by touching them with hands. When the music ends or the screen is not touched for a prolonged period, the display returns to the main menu. In the final results display (d), the success rate and the score are displayed. The success rate starts at 100% and decreases depending on the number of mistakes made. Four messages are displayed depending on the success rate: 'Outstanding' is displayed for a success rate of over 95%, 'very good' is displayed for a success rate of over 85%, 'good' is displayed for success rates of over 75% and 'please try harder' is displayed for success rates of below 75%.

2. Dynamic balance, static balance, and physical function test

1) Subjects

This study was conducted with 21 participants over age 65 without musculoskeletal diseases, who use K welfare center at S city. The participants' average age was 75.4±3.34 yrs, average height was 152.07±4.81 cm, and average weight was 58.35±8.34 kg. Sixteen participants had dominant right legs, and five participants had dominant left legs. The participants exercised with the balance training equipment twice per week for 12 weeks. During weeks 1~3, the participants performed 6~10 repetitions of beginner level exercise (approximately 48 steps per minute) per session. In weeks 4~7, the subjects performed 7~10 repetitions of beginner and intermediate level exercises (approximately 72 steps per minute). In weeks 8~12, the participants performed 6~10 repetitions of intermediate and advanced exercises (approximately 98 steps per minute). Over a span of 12 weeks, 20~30 minute sessions were preceded by 10 minutes of stretching and finished with 5 minutes of stretching, for a total duration of 35~45 minutes. The balance training intensity was determined using the metabolic equivalent of task (MET) as a reference. The intensities were set to beginner, intermediate, and advanced, within an age-appropriate range of 60~216 minutes of MET (Ainsworth et al., 2011). The evaluator explained the procedure before

Figure 4. Software display. Selection of exercise types (a), selection of arm exercises (b-1), display of arm exercise programs (c-1), selection of foot exercises (b-2), display of foot exercise program (c-2), and results display (d).

the experiment began, and participants voluntarily completed the exercise program. This experiment was conducted after receiving approval from the Institutional Review Board.

2) Measurement of variables

(1) Dynamic balance test

The Y-balance test was used to evaluate dynamic balance in the participants (Figure 5). The Y-balance test improved the repetition of the Star Excursion Balance Test, and has high reliability (intraclass correlation=.85+91) (Pilsky et al., 2009). The test is conducted in a one-foot standing position, and measures the maximum extension of the non-supporting leg in three directions (anterior, posterolateral and posteromedial).

A tape measure was used for measurements. The posterolateral and posteromedial directions were marked 135° away from the anterior line. The distance from the center to the point reached by maximum extension was measured in centimeters. To minimize learning effects, the measurements were taken after two practice trials. If the support leg lifted from the ground surface, the extended leg touched the ground surface, or the extended leg could not return to the initial position, the trial was a failure and another trial was conducted to measure the distance.

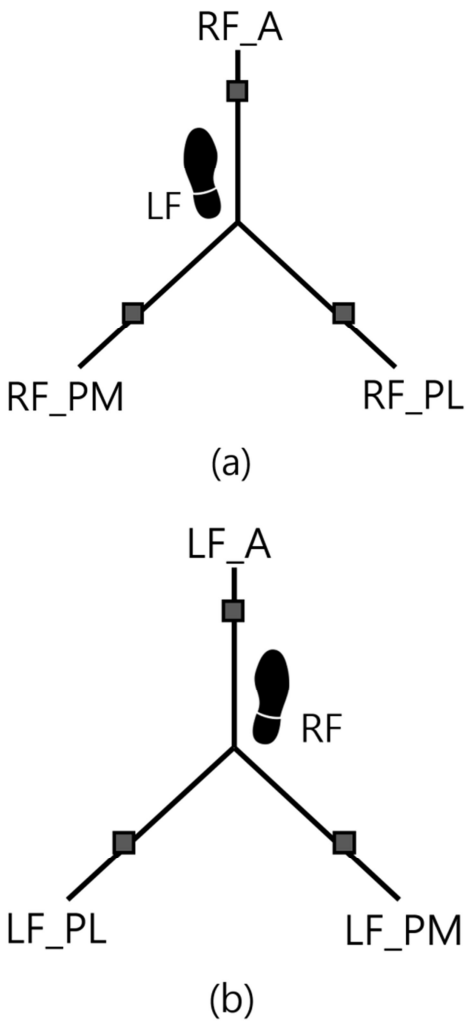

Figure 5. Y Balance Test. Reaching right foot in three directions while standing on left foot (a), reaching left foot in three directions while standing on right foot (b), RF: right foot, LF: left foot, A: anterior, PM: posteromedial, PL: posterolateral.

(2) Static balance test

Balance was evaluated with the one leg static balance test. Standing with both hands on the chest, the time taken for a raised leg to reach the ground surface was measured. There were two conditions for the test: eyes open or eyes closed.

(3) Physical function test

Tests for gait speed and rising speed from a chair have been traditionally used to measure physical function in the elderly (Guralnik et al., 1994). The stair climbing test also measures physical function (Oh et al., 2016).

① Going up and down four stairs

The up and down four stairs test was conducted by measuring the time (sec) participants took to go down four stairs and come up four stairs to their original two-foot standing position. The test began with the evaluator's start signal.

② Rising from a chair five times

With both hands on the chest, participants rose repeatedly from and sat on a chair five times as fast as possible. The total time was measured in seconds.

③ Gait speed

Gait speed was determined by measuring the time (sec) it took participants to walk at usual speed through a 4 m course from a standing position.

3. Statistical analysis

This study of elderly female participants analyzed difference in variables before and after a 12-week training program using balance training equipment designed for the elderly. Variables analyzed were dynamic balance, static balance, and physical function abilities (going up and down the stairs, raising from a chair and gait speed). In order to determine the effectiveness of the training, a paired *t* test was conducted after calculating average and standard deviation. All statistics were done using SPSS 21.0, and the significance level was set to $p<.05$.

RESULTS

1. Rhythmic balance training equipment for the elderly

The training equipment developed in this study adapted the knee flexion from traditional Korean dance, and bears the body weight entirely on one leg. Eight different panels were placed on the floor surface to induce ankle movement in different directions. In order to

maintain interest, ten trot songs and eight folk songs edited with 4/4 beat and 116 beats per minute tempos were uploaded to the software.

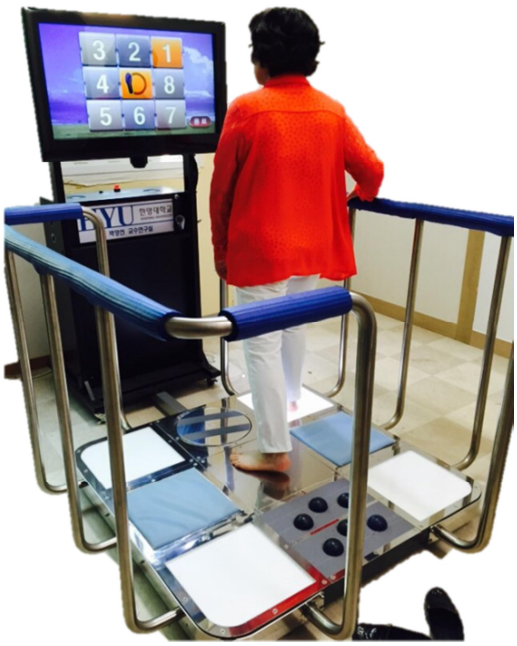

Figure 6. Rhythmic balance training equipment for the elderly.

The results of the exercise were measured through stepping and pressure sensors, and provided to the user as feedback (Figure 6).

2. Results

1) Dynamic balance test

The Y-balance test was conducted after a 12-week program using the rhythmic training equipment for the elderly. The RF_PM, which is diagonal to the standing left foot, significantly increased from 55.50±8.24 cm before training to 62.69±9.48 cm after training (t = 2.89, p<.05). The RF_A increased from 62.12±5.96 cm before training to 63.82±7.39 cm after training, while RF_PL increased from 51.06±11.11 cm before training to 53.81±14.72 cm after training; no significant differences were observed. The LF_A, which is diagonal to the standing right foot, increased from 64.00±5.72 cm before training to 65.74±7.44 cm after training, while LF_PM increased from 58.19±10.06 cm before training to 60.94±13.32 cm after training. LF_PL increased from 54.47±13.02 cm before training to 58.20±13.25 cm after training, but the changes were not significant (Figure 7).

2) Static balance test

The static balance tests on one leg with open eyes and closed eyes

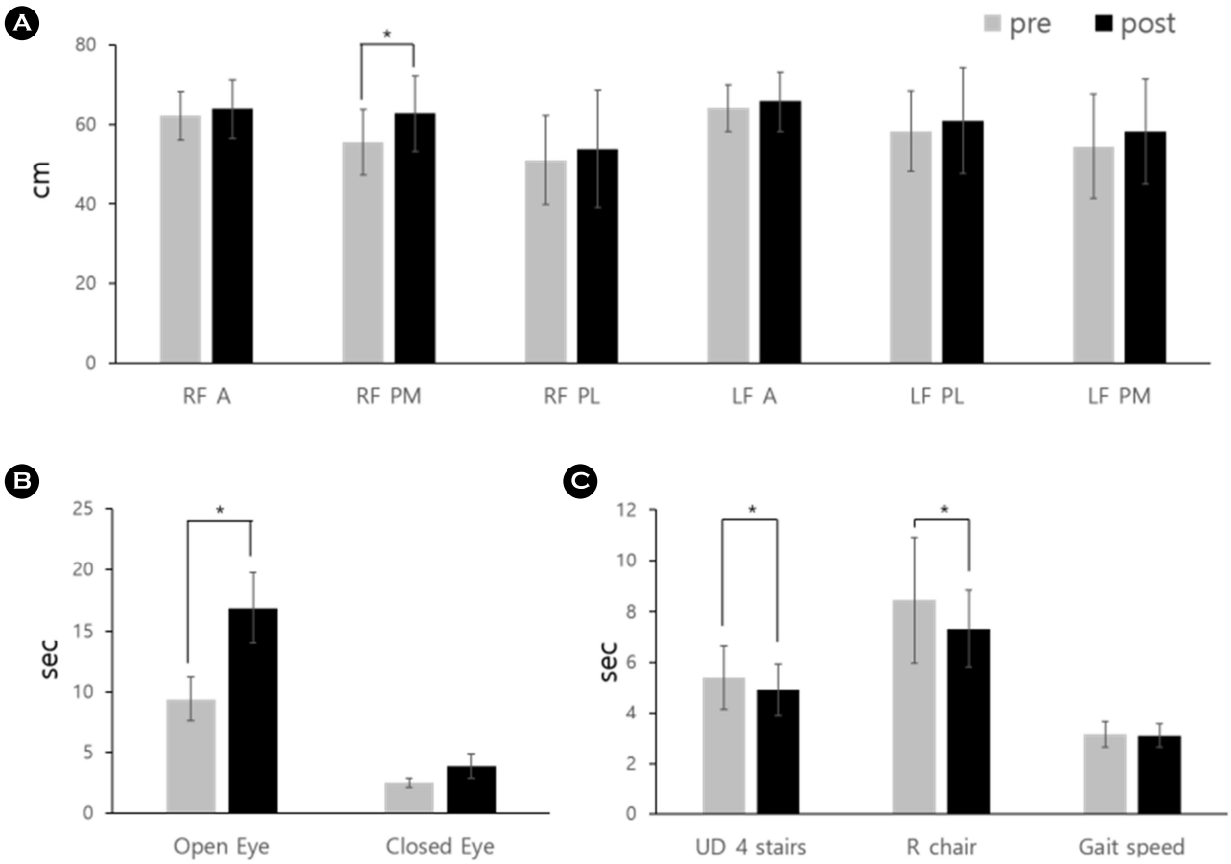

Figure 7. Result of dynamic balance (A), static balance (B), and physical function (C). RF: right foot, LF: left foot, A: anterior, PM: posteromedial, PL: posterolateral, UD_4 stairs: up and down 4 stairs, R_chair: rising from a chair 5 times.

were conducted before and after 12 weeks of exercise on the rhythmic balance training equipment for the elderly. The results show a significant increase in static balance on one leg with open eyes, from 9.41±1.84 sec before training to 16.88±2.90 sec after training (t = 2.32, p<.05). In the static balance test on one leg with closed eyes, there was an increase from 2.51±0.39 sec before training to 3.87±0.97 sec after training. The change was not significant (Figure 7).

3. Physical function test

The stair climbing test results improved significantly from 5.40±1.24 sec to 4.92±1.02 sec after 12 weeks of exercise on rhythmic balance training equipment (t = 2.19, p<.05). Rising speed from a chair significantly improved from 8.44±2.47 sec before training to 7.33±1.52 sec after training (t = 2.76, p<.05). Although the gait speed improved from 3.24±0.51 sec before training to 3.10±0.46 sec after training, the change was not significant (Figure 7).

DISCUSSION

Balance and quality of life were improved in participants who underwent 12 weeks of exercise on the rhythmic balance training equipment developed in this study, compared to elderly participants who only underwent walking exercises (Lee & Park, 2014). Participants also showed decreased fear of falling and improved confidence of balance after nine weeks of training (Lee & Park, 2016).

In this study, the positive effects of a 12-week program using the rhythmic balance training equipment on dynamic balance, static balance and daily life physical functions were confirmed. The results show that significant improvement was observed only in RF_PM, which is diagonal to the standing left foot, after training for dynamic balance (p<.05). A study by Roghani et al. in 2013, in which elderly participants underwent walking training wearing weighted jackets, reported significant improvements in Y-balance in all directions. The goal of this study was to improve the balance in the elderly using steps. A program with step exercises in eight different directions and exercise on both feet provides proportional training without deviations. While previous studies are characterized by voluntary walking in the elderly, this study is characterized by proportional exercise that can reduce the differences in training between the left and the right foot. Significant improvements were possibly only observed in RF_PM, which measures Y-balance of the right foot diagonally from the left support leg, because diagonal movement of the right foot while supporting with the left leg is the most difficult direction for the elderly to move (Roghani et al., 2013). The relatively better dynamic balance of the left foot compared to the right foot could have also been influenced by a difference in lower limb strength. A study by Park & Lee in 2012 reported that isokinetic strength of the left leg was weaker than the right leg in the elderly. While going down stairs, the braking and the driving forces of the left leg were observed to be greater than the right leg, indicating that dynamic stability is relatively less in the left leg. A study by Kim & Sohn in 2016, which compared the isokinetic muscle functions in the elderly, also reported that the balance of the left leg is relatively lower than the right leg based on the muscle deficit rate and strength measurements of knee flexors and extensors. The lower limb muscle imbalance is especially large in elderly women. Since the training equipment developed in this study can uniformly train the left and the right legs, it can be assumed that the intensity of the exercise was identical in both legs. It can therefore be inferred that the balance of the relatively weaker left leg was improved at a greater magnitude.

The static balance test on one leg produced significant results only when the eyes were open (p<.05). A study by Rahal et al. in 2015, which conducted tai chi and ballroom dance training with elderly participants and compared improvements in static balance, reported that only tai chi training significantly improved static balance when the eyes were open. This indicates that results vary depending on the type of exercise training. Tai chi's characteristics of moving on the supporting surface, long one-legged support time, and movement of the center of mass induced muscle strengthening and therefore improved static balance when the eyes were open (Ramachandran, Rosengren, Yang, & Hsiao-Wecksler, 2007). It can be inferred that the repetitive flexion and extension of the knee and long one-legged support time in this study had similar movements as tai chi, thereby improving static balance. A paper by Kim, Hwang & Kim in 2010 reported that visual regulation of balance is effective for maintaining static balance, similar to the results of this study showing improved static balance when the eyes were open.

Results of previous studies explain why training with closed eyes did not improve static balance in this study. It has been reported that balance is relatively more affected by the vestibules. A paper by Rahal et al. in 2015 reported that ballroom dance training (conducted while repetitively rotating counterclockwise) improved static balance when the eyes were closed. A study by Park, Kang & Lim in 2012 also reported that rotation or rolling training effectively strengthened vestibular functions. It can therefore be inferred that exercising on the balance training equipment in this study did not have any effects on vestibule-stimulating balance.

Measurements of daily life physical functions in the elderly showed significant differences between going down the stairs and rising from a chair (p<.05). A study by Mayagoitia, Harding & Kitchen in 2016 reported that the stair-ascending test is more important than the walking test to determine movement problems in the elderly. In this study, the improvements in going up and down the stairs with no change in gait speed indicate that the use of training equipment improved the ability to support body weight with one leg. Rising from a chair has traditionally been used to determine lower limb muscle strength, since it requires lower limb muscle-activating movement (Yoshioka, Nagano, Hay, & Fukashiro, 2012). A study by Pijnapels, Reeves, Maganaris & Van Dieen in 2008 reported that improved lower limb muscle function in the elderly is an important factor that can reduce the risk of falling, which is mainly caused by decreased physical function. A study by Straight, Brady & Evans in 2015 also reported that lower limb muscle strength is crucial for technical activities such as rising from a chair or climbing up stairs. It can be inferred that the significant improvements in rising from a chair and going up and down the stairs observed in this study were due to the increase in lower limb strength created by the traditional Korean dance movement, which flexes the knee and

bears body weight completely on one leg.

It can be inferred that the use of the training equipment for the elderly developed in this study improved dynamic and static balances, which positively affected lower limb strength.

The training equipment developed in this study was designed for the elderly; only the effects of exercise training on technical evaluations, which can be tested with the daily-life activities of the elderly, were confirmed. Further studies on the effects of the training on the elderly will hopefully evaluate muscle strength during specific movements in the elderly.

CONCLUSION

In this study, knee flexion movements from traditional Korean dance was adapted, 8 different panels inducing diverse ankle movements were installed, and the sentiments of the elderly were taken into account to develop balance training equipment that could be self-operated by the elderly.

Three theories were established to confirm physical function improvements caused by the training equipment. First, the training equipment will improve dynamic balance in the elderly. Second, it will improve static balance in the elderly. Third, it will improve daily life physical functions. The following conclusions were made on the three theories:

First, exercising on the rhythmic training equipment for the elderly improved dynamic left leg balance.

Second, exercising on the rhythmic training equipment for the elderly improved static balance when the eyes were open.

Last, exercising on the rhythmic training equipment improved lower limb strength-related physical functions of going up and down stairs and rising from a chair.

ACKNOWLEDGEMENTS

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