J. Phys. Ther. Sci. 31: 132–137, 2019

The Journal of Physical Therapy Science

Original Article

Effects of Taekkyon training on balance control during stair descent in community-dwelling older adults

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Abstract. [Purpose] The purpose of this study was to examine the effects of Taekkyon training on balance control during stair descent in community-dwelling older adults. [Participants and Methods] Participants were randomly assigned to either the Taekkyon group or wellness education group. The participants in the Taekkyon group received Taekkyon training 2 times a week for 12 weeks. The participants in the wellness education group participated in a health education program 1 hour weekly for 12 weeks. Subjects stood in a predetermined position on the top of the custom-built 3-step staircase and then descended the stairs at a self-paced speed. The changes in the translation of the center of pressure before and after Taekkyon training were measured. [Results] The Taekkyon group showed a greater increase in the displacement of the center of pressure in the anteroposterior and mediolateral directions as well as the average velocity of the center of pressure in posttesting than the wellness education group. The Taekkyon group also showed a significant increase in all measures after Taekkyon training. However, little change was found in all measures in the wellness education group. [Conclusion] These findings support the use of Taekkyon training as an effective fall-preventive rehabilitation program to reduce falling in older adults.
Key words: Aging, Falling, Taekkyon

(This article was submitted Sep. 17, 2018, and was accepted Nov. 2, 2018)

INTRODUCTION

Falls in older adults can result in serious injuries, loss of functional independence, disabilities, and even increased mortality[1)]. Fall-related injuries and its associated health care costs pose a serious public health problem for the older population. Thus, it is warranted that falling and fall-related injuries in older adults be minimized. Numerous studies[2–4)] have suggested that exercise intervention improves balance control in older adults, and reduces age-related risk factors that are associated with falls.

Some therapists in South Korea have recently advocated martial art techniques such as Taekkyon in clinical practice for improving balance in older adults, and have recommended it as a fall prevention strategy for older adults, although its mechanism of action in this population has not yet been investigated. Taekkyon, a Korean martial art, has been trained for a long period. The motion of Taekkyon is fluid and involves rhythmical movements. For example, Pumbalkki, a basic stepping motion, takes a triangular form similar to the Chinese character Pum (品); it starts from one angular point of the triangle, stepping forward to the other points with the left and right legs in each direction, and moving backward to the original point.

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It is considered physically gentle due to its fluidic movements, which involve knee bending and extending as well as mild body twists. This motion is suggested as the sequential drive of lunging and squatting, which induce eccentric contractions of the quadriceps.

Negotiation of stairs is a common activity that is frequently encountered in daily life, and a fall on stairs is responsible for approximately 10% of the total number of accident cases[5, 6]. Although both stair ascent and descent are quite demanding for the elderly, stair descent is the most challenging aspect of stair negotiation, and is responsible for three-quarters of all staircase accidents[5].

The center of pressure (COP) is commonly used as an indicator of balance and postural control[7], and decreased capability of generating COP displacement has been seen in older adults[8–11]. Changes in the translation of the COP reflect central nervous system's response to movement in the body's center of mass (COM)[9]. Thus, knowledge of changes in the translation of the COP during stair descent after Taekkyon training may be useful for understanding the mechanisms of exercise-induced adaptation in the balance control system.

Therefore, the aim of this study was to examine the effects of Taekkyon training on balance control during stair descent in community-dwelling older adults. It was hypothesized that: (i) Taekkyon training would demonstrate increases in the anteroposterior (A-P) and mediolateral (M-L) displacement of the COP, as well as the average velocity of the COP, with no difference in these measures for the wellness education (WE) group between pretest and posttest; and that (ii) Taekkyon training would lead to a greater increase in these measures than WE.

PARTICIPANTS AND METHODS

A total of 50 older adults (mean age, 73.2 ± 6.3 years, range: 65–83 years) were randomly assigned to the Taekkyon group (n=25; 73.5 ± 7.6 years, range: 65–83 years) or the WE group (n=25; 72.8 ± 6.2 years, range: 65–82 years), according to the exercise allocation information stored in consecutively numbered opaque sealed envelopes in order to ensure blindness.

Participants from both groups who agreed to participate in the study met the following criteria: (i) adults aged >65 years; (ii) Mini-Mental State Examination (MMSE)[12] score >24; (iii) BBS[13, 14] score >45; and (iv) no experience with Taekkyon, Tai Chi (TC), or other exercise programs in the prior 6 months. The exclusion criteria were as follows: (i) cardiovascular disease, musculoskeletal disorder, ischemic heart disease, orthostatic hypotension, dementia, or musculoskeletal disease; and (ii) an inability to walk independently without a mobility aid (cane, walker) or help. Prior to study enrollment, all participants provided written informed consent. The study was approved by the ethics committee and institutional review board at Korea University Medical Center (IRB NO. KU-IRB-13-102-A-2). The patients' demographic characteristics are presented in Table 1, while a flow chart of each stage is presented in Fig. 1.

Two experienced Taekkyon instructors and four assistants taught Taekkyon to the participants in the Taekkyon group. Participants in the Taekkyon groups received training for 1 hour per day, twice weekly, over a period of 12 consecutive weeks (24 total sessions) at two different silver community welfare centers in Seoul, South Korea. The Taekkyon group participated in a 23-form modified Taekkyon exercise program. The first 10 minutes were spent in performing warm-up exercises, followed by 40 minutes of Taekkyon training, and then continuing to the 10-minute cool-down exercise. The Taekkyon exercises included the following: (i) with legs spread shoulder-width apart, kicking the left and right feet alternately; (ii) fluid triangular foot walks with the knees flexed/extended; (iii) with the spine erect, raising the left/right knee in turn to the limit; (iv) continuously moving the body's center of mass; and (v) spreading out the hands and rhythmically shaking the arms back and forth at 45-degree angles during the foot walks. Along with these basic movements, motions involving upper and lower extremities were used to improve the capability of maintaining the center of weight in a situation of falling down. Synchronized breathing was integrated into Taekkyon movement, and a cycle of 23 movements was repeated for 40 minutes. The warm-up exercises included gentle stretches for the shoulder, necks, arms, and legs, followed by a trunk stretching exercise, a weight shift with trunk rotation, and active arm swinging. The cool-down exercises involved stretching the arm and leg muscles, accompanied by deep abdominal breathing and relaxation. Instruction was given to aid in the learning of the new movements, and to review the movements learned in previous sessions. Each Taekkyon practice session involved musical accompaniment.

The participants in the WE group participated in a health education program one hour weekly over a period of 12 consecutive weeks (12 total sessions) at a silver community welfare center in Seoul, South Korea. They attended lectures about diet and nutrition, fall prevention, exercise and balance, pharmacological management, as well as mental health issues such as stress, depression, and life changes. Participants in the WE group were instructed to not participate in any form of regular exercise programs, but were asked to maintain routine activities.

Participants negotiated a custom-built standard 3-step instrumented staircase. The dimensions of the staircase were as follows: step height, 17 cm; tread length, 28 cm; step width, 90 cm. Two force platforms (Model: OR6-7-OP, AMTI, Watertown, MA, USA), embedded in the first step of the staircase as well as in the level walkway (5 m in length and 1.4 m in width) directly in front of the staircase, measured the ground reaction forces (GRF) during stair descent. Each step was constructed independently using a solid steel frame securely bolted to the ground. The vertical steel frames had a width and depth of 8 cm and 4 cm, respectively, which ensured a mechanically stiff structure that enabled forces to be recorded from the first step and the ground. Amplified force platform signals were sampled online at a rate of 1,000 Hz for 30 seconds (AMTI). The COP

Table 1. Demographic characteristics of the participants

Characteristic	Taekkyon group (n=23)	WE group (n=23)
Gender (M/F)	14/9	15/8
Age (yrs)	72.6 ± 3.3	71.2 ± 4.8
Height (cm)	160.5 ± 9.2	159.3 ± 8.4
Weight (kg)	60.8 ± 8.1	59.6 ± 6.2
MMSE	27.8 ± 1.4	28.2 ± 1.6
BBS	54.8 ± 1.8	54.8 ± 1.2
BMI (kg/m^2)	24.2 ± 4.3	23.8 ± 4.1

Values are mean ± SD.
WE: Wellness education; M: Male; F: Female; MMSE: Mini-Mental State Examination; BBS: Berg balance scale; BMI: Body Mass Index.

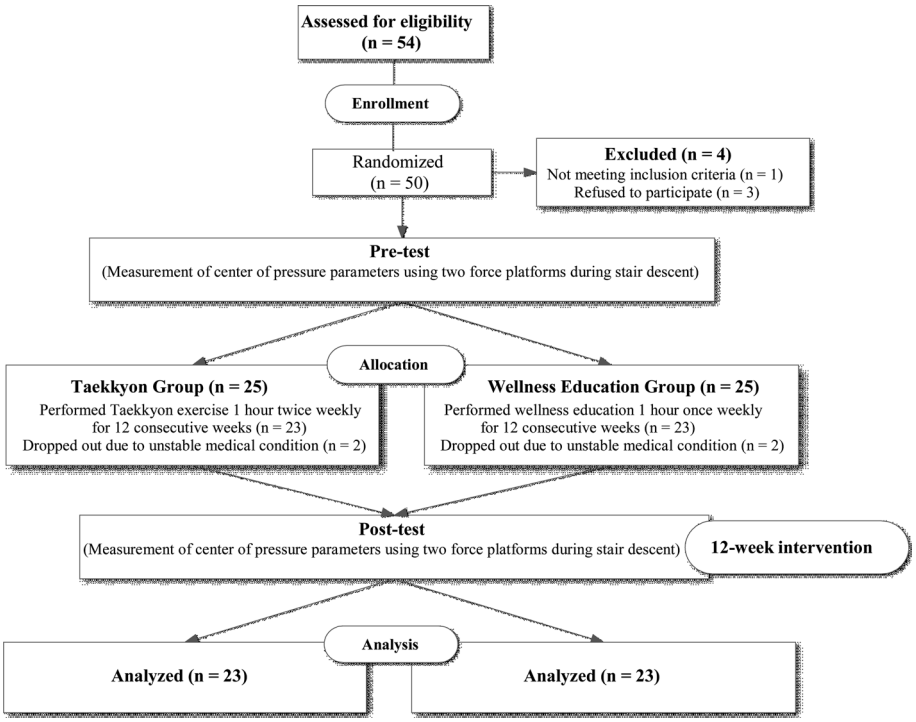

Fig. 1. Flow diagram of the study.

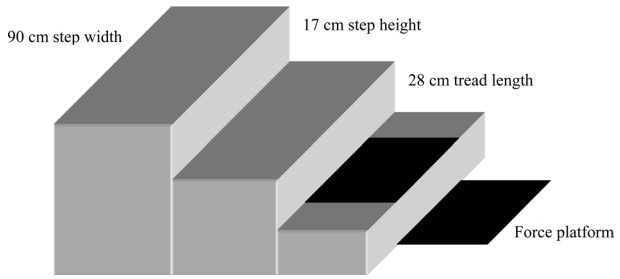

Fig. 2. Experimental setup of the staircase with two force platforms used in the present study.

was defined as the point of application of the GRF vector in three directions on the force platform, and was analyzed using BioAnalysis v2.0 software (AMTI). The experimental setup is shown in Fig. 2.

For each trial, the participants stood in a predetermined position on top of the staircase. Participants were then asked to negotiate the stairs at a self-paced speed, with the left limb in response to auditory cues, and continue for several strides after striking the force platform on the floor. Participants were instructed to place only one foot on each step (foot-over-foot). The analysis corresponded to the initial ground contact of the right foot on the second step down (first force platform), and the initial ground contact of the left foot on the floor (second force platform). This part of the analysis was chosen to represent a "steady-state" step. Participants completed two practice trials and approximately three experimental trials.

A required sample size of 46 participants (23 for each exercise group) was estimated using the G*Power statistical power analysis program version 3.1.3 (FranzFaul, Universitat Kiel, Kiel, Germany) for analysis of covariance (ANCOVA), with an alpha level of 0.05, effect size of 0.50, and power of 0.90[15–17]. The effect size was calculated as described by two previous randomized controlled trial studies[18, 19]. The analyses were performed on an intention-to-treat principle; thus, all available data from all subjects were included in the analysis.

The independent t-test was used to examine intergroup differences in baseline demographic characteristics. Changes in the dependent variables between the pre-test and post-test presented in both groups were compared using ANCOVA with a regression model that modifies the initial differences of the variable examined between the two groups based on a pretest measure. The paired t-test was used to compare the changes between pre- and post-test measurements within each group. The dependent variables included the A-P and M-L displacements of COP as well as the average velocity of COP. The A-P (or M-L) displacement of COP was defined as the total distance (or difference) between the minimum and maximum A-P (or M-L) COP location for the duration in which either the right or left foot was in contact with the force platform. The average velocity of COP was defined as the average velocity traveled by COP for the duration in which either the right or left foot was in contact with the force platform. Statistical significance was set at values of $p<0.05$. Statistical analyses were performed using SPSS version 21.0 (IBM, Armonk, NY, USA).

RESULTS

Two participants from each group (four total) withdrew from the study due to health deterioration. Thus, a total of 46 participants finished the study, and all participants in the Taekkyon (n=23; 72.6 ± 3.3 years, range: 65–83 years) and WE (n=23; 71.2 ± 4.8 years, range: 65–83 years) groups completed the initial and post-training measurements. Data from all 46 participants were used in the final statistical analysis. The use of the independent sample t-test demonstrated no significant intergroup differences in age, height, weight, MMSE score, BBS score, and body mass index at baseline (Table 1).

The ANCOVA indicated that for the A-P and M-L displacement of the COP, as well as its average velocity, significant differences were found between the Taekkyon and WE groups. The Taekkyon group exhibited greater increase than the WE group in the A-P ($F_{(1,43)}=16.0$, $p<0.01$) and M-L ($F_{(1,43)}=15.2$, $p<0.01$) displacement of the COP, as well as the average velocity of the COP ($F_{(1,43)}=18.2$, $p<0.01$). Moreover, a comparison of the pre- and post-intervention revealed statistically significant increase in the Taekkyon group in the A-P ($p<0.01$) and M-L ($p<0.01$) displacement of the COP, as well as the average velocity of the COP ($p<0.01$). However, no significant differences were found in all measures in the WE group. More details about the outcomes in both groups for the measured dependent variables are provided in Table 2.

Table 2. Changes in COP parameters (cm) by intervention conditions for each group

Parameter	Taekkyon group (n=23), M ± SD		WE group (n=22), M ± SD	
	Pre-intervention*	Post-intervention	Pre-intervention*	Post-intervention
Right foot				
A-P displacement (cm)†	11.8 ± 3.2	28.7 ± 5.2‡	11.1 ± 4.3	12.2 ± 3.9
M-L displacement (cm)†	6.1 ± 3.3	8.5 ± 4.1‡	7.9 ± 3.6	7.1 ± 4.3
COP velocity (cm/sec)†	76.9 ± 15.9	95.3 ± 29.4‡	79.1 ± 16.1	78.8 ± 17.3
Left foot				
A-P displacement (cm)†	12.8 ± 7.2	23.6 ± 3.8‡	13.5 ± 4.3	14.9 ± 4.6
M-L displacement (cm)†	7.4 ± 2.8	10.8 ± 4.2‡	6.8 ± 2.3	7.8 ± 3.2
COP velocity (cm/sec)†	73.1 ± 14.3	88.5 ± 15.8‡	75.4 ± 19.5	77.6 ± 17.8

Values are mean ± SD.
WE: Wellness education; COP: center of pressure; A-P: anteroposterior; M-L: mediolateral.
*No significant differences ($p>0.05$) between the Taekkyon group and WE group before intervention for all measurements.
†Significant differences by analysis of covariance for comparison of post-intervention scores of the two groups adjusted for baseline performance ($p<0.01$).
‡Significant change ($p<0.01$) within the group (Taekkyon and WE) at post-intervention compared with pre-intervention by a paired t-test.

DISCUSSION

To the best of our knowledge, this is the first study to compare the effects of Taekkyon and WE exercise programs on the COP parameters for older adults who have descended a staircase both before and after Taekkyon training. The results of this study confirmed the hypothesis that the Taekkyon training would demonstrate increases in the A-P and M-L displacement of the COP as well as in its average velocity, but no differences in these measures for the WE group between pre-test and post-test. We also confirmed the hypothesis that the Taekkyon group would exhibit greater improvement than the WE group in all measures.

Control of the COM via translation of the COP during stair descent provides an important indication of dynamic postural stability. In this study, Taekkyon training led to significant increases in the COP parameters in both feet during stair descent. The backward displacement of the COP during stair descent generates the forward movement necessary to initiate gait[11]. In this study, participants of the Taekkyon exercises were able to increase A-P displacement of the COP at an average of 16.9 cm and 10.8 cm for both the right and left feet from the baseline, whereas the WE group participants showed little change in the same variables between pre-testing and post-testing.

Although no previous studies have presented any direct comparisons on the COP parameters between Taekkyon and WE, several previous studies have reported on the effects of TC exercise programs in COP parameters in older adults. Hass et al.[20] and Kim[21] reported an increased backward movement of the COP during level walking and while stepping over an obstacle on the ground after TC training in fall-prone adults. TC participants were able to increase the magnitude of the A-P displacement of the COP closer to the magnitude reported for healthier elderly participants[22], whereas participants from the control group showed little change in the displacement of the A-P COP.

The control of the whole body COM in the M-L direction through manipulation of the M-L COP during walking is important for the maintenance of lateral stability, which may be compromised in elderly paticipants[23–25]. In the current study, after the Taekkyon training, the average M-L COP displacement of both feet for the Taekkyon group participants was 9.7 cm, demonstrating a 43% increase as compared to the pre-testing results; however, little change was found in the M-L displacement of the COP between pre-testing and post-testing of the WE group. This finding indicates that Taekkyon training positively influenced the magnitude of the M-L displacement of the COP. It is assumed that the greater displacement of the M-L COP is likely due to improved coordinated action of the hip abductor and adductor muscles after Taekkyon training[26]. The stance-side momentum is generated during stair descent by the swing limb hip abductors that propel the COP laterally toward the swing limb[27]. Thus, muscle activity at the ankle and hip tend to propel the COM forward and toward the intended stance limb. Although direct comparisons on the COP parameters in the M-L displacement of the COP between pre-testing and post-testing is difficult, a previous study on TC[21] also reported an increased M-L COP movement while crossing an obstacle after TC in fall-prone adults.

The velocity of the COP also provides valuable information about how older adults modulate gait during stair negotiation. In the current study, the Taekkyon participants demonstrated a 23% increase in the COP velocity for both feet, which may indicate an improvement in maintaining balance during stair descent, because a greater COP velocity was found during obstacle crossing in young adults, as compared to the COP velocity of older adults[28].

There are several limitations that need to be addressed. First, no follow-up data were collected; therefore, it is impossible to determine the long-term outcomes of the intervention. Second, because the sample size in our study was limited and its conclusions were based on samples of older adults only, we must be cautious in interpreting the results. Third, this study used a staircase of only three steps, which may not have allowed simulation of actual stair descent. Finally, only a subset of the parameters involved in maintenance of balance was considered in this study. Further research should investigate the potential benefits of Taekkyon training for other aspects of physiological changes, such as muscle strength, flexibility, proprioception, vestibular inputs, and sensory organization changes, which might affect balance.

In conclusion, findings from this study suggest that Taekkyon training influenced the generation of momentum through an increase in the magnitude of COP movement in the A-P and M-L directions, and in the maintenance of balance, thereby improving the ability of older adults to descend stairs. Taekkyon training also resulted in an increase of the COP velocity during stair descent. These findings support the use of Taekkyon training as an effective fall-preventive rehabilitation program to reduce falling in the elderly, and to counteract deficits in motor and sensory function associated with aging.

Funding

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2017R1D1A1B03028734).

Conflict of interest

None.

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