Effects of Multidirectional and Variable-Speed Body Weight Supported Treadmill Training on Balance Rehabilitation for Fall Prevention among Community-dwelling Elderly Persons

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ABSTRACT

Objectives: To assess the effectiveness of multidirectional and variable-speed body weight supported treadmill training (BWSTT) in walking and balance rehabilitation for elderly persons with a history of falls or with perceived impaired balance.

Setting: The Bang Mueang Commune Municipality, Ban Bang Khae (Bang Khae Home for Older Persons), Rachathewa Sub-district Health Promotion Hospital, Samrong Klang Sub-district Health Promotion Hospital and Public Health Center 25 (Huai Khwang).

Study design: Retrospective study.

Subjects: Elderly persons aged 60 years or over with a history of falls or with perceived impaired balance over the past six months.

Methods: The individual participants underwent BWSTT twice a week for six weeks, the difficulty of which was adjusted step-by-step. Before the training, they were interviewed about their history of falls over the past six months and were assessed with the following tests – the Berg Balance Scale (BBS) test, Timed Up and Go Test (TUGT) and stop-watch assisted analysis of average temporal spatial gait parameters such as gait speed, cadence and step length. The tests were conducted two other times, with one carried out immediately at the end of the six weeks training and the other one six months after it (six months follow-up).

Results: Out of 233 participants (38 males and 195 females), 46 of them reported a history of falls over the past six months before their project enrollment, with an average fall rate of 0.59 falls/person/year. During the training period, no fall incident was reported; however, on the six months follow-up, 17 of them reported a fall/falls, with a rate of 0.20 falls/person/year, which was 66.10 percent lower than the average fall rate before the training. The assessments conducted immediately after the end of training and on the six months follow-up suggested that the scores of the BBS test, TUGT and the tests on comfortable gait parameters, i.e. gait speeds, cadence and step lengths improved compared with those before the training at a statistically significant level with a $p<0.001$.

Conclusion: Biweekly 30-minute BWSTT over a six weeks period provided elderly persons with a history of falls or perceived impaired balance a significant improvement in walking and balance ability and a significant reduction in the fall rates at the end of the 12 training sessions and at six months follow-up.

Keywords: fall, walking, balance, body weight supported treadmill training, elderly persons

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Introduction

Performance of body systems, i.e. the cardiac and pulmonary system, nervous system, as well as bone and muscular system tends to decline.[(1)] Reduced muscular strength, body flexibility and body endurance are example of factors that contribute to impaired body balance among elderly persons[(2)] which increase their risk of falls.[(3-5)] Some elderly persons are more likely to experience a fall incident than others.[(6,7)] For example, those with a history of falls have a higher risk of repeated falls.

Falls among elderly persons is a major public health issue. Prevalence of falls is increasing in Thailand,[(8)] in parallel with the increased proportion of elderly population.[(9)] This leads to increased number of injuries, complications, disabilities, risks of death and economic loss to the elderly, their family and society.[(10)]

Exercise to optimize body balance for fall prevention should consist of training which improves muscular strength, body coordination, movement and flexibility.[(11-13)] Different types of exercise have been introduced as a tool for improving body balance, e.g. walking, running, calisthenic type exercise, Chinese boxing, yoga, Tai Chi and balance training with help from specialized equipment. However, these types of exercise proved to be effective in providing only a 30 percent reduction in falls.[(14,15)]

The rehabilitation of balance and walking ability by means of body weight supported treadmill training (BWSTT) differs from other balance training techniques. Such training method could simultaneously address all major exercise need of elderly persons with balance deficit such as, multi-directional dynamic balance training in the context of walking, as well as functional stretching, functional strength training and cardiopulmonary training. It's high task specificity nature of balance training and high repetition differentiate this training from other training methods.[(16)]

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The BWSTT enables elderly persons to practice walking and balancing without the fear of falling. This method is perhaps more efficient than any other training method. A few years ago, a research had conducted on the effects of the BWSTT on walking and balance ability of community-dwelling elderly persons.[17] It revealed that the BWSTT significantly increased gait speeds and step lengths and more importantly, it reduced the fall rate by over 90 percent. Such reduction of fall rates is much higher than other well-known balance training methods. However, there were some limitations to the scaling up of the results. That is, it was inconvenient for most elderly participants to visit the hospital to join the training. Therefore, the Samrong Ruam Jai Foundation expanded the project into the community level by hiring physiotherapists and providing necessary equipment for operations at different community centers which were accessible to a large number of elderly persons. This aimed to rehabilitate walking and balance among elderly persons with a history of falls or perceived impaired balance over the past six months before they participated in the training. The second project employed the same training method and data collection technique as the earlier one. In 2017, this project received a national model project award from the Department of Social Development and Welfare, the Ministry of Social Development and Human Security.

Due to the Foundation's continuous operation and information gathering, data on training and results of the rehabilitation in a larger group of elderly persons become available. Thus, the authors decided to retrospectively analyze the collected data from this second project to confirm the effectiveness of multidirectional and variable-speed BWSTT in the rehabilitation of balance and walking ability among elderly persons with impaired balance. The data could support this balance training as an alternative for trunk balance rehabilitation among Thai elderly persons at the national level.

Materials and Methods

Participants: Community-dwelling elderly persons

Inclusion criteria:

- Aged 60 years or over
- Having a history of falling over the past six months or perceived impaired balance, e.g. the fear of falling

Exclusion criteria:

- Dementia or reduced awareness which results in the inability to understand and cooperate in the training
- Painful conditions of joint, bone and muscular systems of the lower limbs
- Unstable medical symptoms
- Inability to tolerate exercise even at a minor level equivalent to safe comfortable gait speeds

Materials

The set of training device consisted of a body weight support frame and a motorized treadmill (see Figure 1) with a minimum speed of 0.2 km per hour, which suited training elderly persons with impaired body balance. Participants wore a body harness which was attached to the body weight support metal frame via a vertical rope. No amount of weight support force is being measured.

Interventions

1. Selecting elderly persons who were eligible based upon the screening criteria and who gave consent to receive an assessment on readiness for the training. All pre- and post-treatment data collection was done by the same physiotherapist who supervised the training of each subjects.
2. Interviewing them about a history of falls (number of falls) over the past six months.
3. Assessing their balance by using the Berg Balance Scale (BBS).
4. Calculating their fall rate, whereby the fall rate equated to the total number of falls of all elderly persons who had a fall history over the past six months, multiplied by 2 and divided by the number of elderly persons participating in the project.
5. Assessing their walking ability using the average Timed Up and Go Test (TUGT) and the tests on comfortable gait parameters, i.e. gait speeds, cadence and step lengths by calculating the parameter values through the following standard procedures:

- Asking the participants to walk on a flat floor of a building in a straight line; recorded the time and the number of steps taken for a 10-m walk, in reference to the marks of the timer start line and the timer stop line attached to the floor; and asked them to stand to prepare for a 2.5 meters walking from the timer start line and walking pass the timer stop line to stand at the destination, which was 2.5 meters away from the timer stop line. This aimed to measure the gait values with a constant speed rate.
- Calculating the average gait speed in kilometers per hour by dividing 36 by the time (in seconds) taken to take a 10-m walk.
- Calculating the average cadence (the number of steps per minute) by dividing the number of steps by the time (in seconds) taken to complete a 10-m walk and multiplied this by 60.
- Calculating the average step length (in centimeter) by dividing 1,000 by the number of steps counted for a 10-m walk.

6. Training them in walking at the project site (free of charge) twice a week for six weeks (altogether 12 training sessions). The training program consisted of BWSTT, as shown in Figure 1, alternating with sitting for a rest for a total of 30 minutes. The difficulty of the training was adjusted step by step.

Step 1: Walking forward at a comfortable speed while touching the handrails to help with balancing.

Step 2: Walking forward with increasing and decreasing gait speeds without touching handrails.

Step 3: Walking forward at a comfortable speed, alternating with walking to the left and right while touching the handrails to help with balancing.

Step 4: Walking forward, alternating with walking to the left and right with increasing and decreasing gait speeds while touching the handrails.

Step 5: Walking forward at a comfortable speed, alternating with walking to the left and right and walking backward while touching the handrails to help with balancing.

Step 6: Walking forward, alternating with walking to the left and right and walking backward with increasing and decreasing gait speeds without touching handrails.

Step 7: The same as step 6 and then undergo an increase in treadmill movement without being given early warning, or throw a ball to and receive a ball from a supervising physiotherapist.

All of the participants had to start their trainings at the step 1. During every training session, they had to wear the body weight support all the time to boost their confidence and prevent a fall during walking training. However, the body support force was kept as low as possible and gradually reduced until so that it reached 0 kilogram.

In the following steps, they were not allowed to use body support force. When the supervising physiotherapist determined the participants could maintain their balance during their walk, they let them shift to the next step. Those who showed better balance in the first training session could move to the next steps quickly.

They were instructed not to do any extra balance training other than this twice a week BWSTT under supervision of the physiotherapist in the community centers.

7. Repeating the assessment of the effectiveness of the rehabilitation based on the scores of the BBS, TUGT and other tests immediately at the end of the six weeks training period and again on a six months follow-up.

Statistical analysis

The data were analyzed using the Stata Program.

1. General data, the fall rate over the past six months, the BBS score, TUGT score, gait speed, step length and cadence were presented in the form of mean values, percentages and standard deviations (SD).

2. Comparative data on the fall rate over the past six months, the BBS score, TUGT score, gait speed, step length and cadence before and after the training were analyzed by using the paired t-test for normally distributed data and the Wilcoxon Signed Ranks Test for abnormally distributed data.

This research underwent a consideration on ethics in human research by the Medical Organization of Samrong Hospital, according to its Approval Letter, no. 2562/001.

Results

From May 2016 to February 2019, there were 233 elderly persons who completed 12 training sessions, which consisted of 38 males and 195 females with ages ranging from 60-93 years (mean 69.23 years, SD 6.91). One hundred and seventy-seven of them had one or more chronic diseases – 47 with diabetes, 102 with hypertension, 13 with heart disease, 90 with dyslipidemia and 65 with other diseases, as presented in table 1.

A subject interview revealed that 46 of them (19.74 percent) had a history of falls over the past six months before the project enrollment (69 falls), with a fall rate of 0.59 falls/person/year; 233 were assessed immediately after the training was completed; and 188 underwent the six months follow-up.

During the six weeks training period, no fall incident occurred. The assessment undertaken immediately after the completion of the six weeks training revealed that 28 of them (12.02 percent of all participants) had a history of falls over the last six months before the project enrollment, with a fall rate of 0.24 falls/person/year, which decreased from that before the training by 59.32 percent.

Based upon the six months follow-up, 17 of them (9.04 percent of those who were followed-up) had a history of falls over the past six months, with a fall rate of 0.20 falls/person/year, which decreased from that before the training by 66.10 percent.

Tables 2 and 3 show improvements of the fall rates, the BBS score, the TUGT score and the gait parameters, i.e. gait speed, cadence and step length as a result of training. The improvements reach statistically significant level with a $p<0.001$ in both comparisons, namely the before training versus immediately after the training and before training versus six months follow-up. Table 4 compares assessment results obtained immediately after the training versus the results from the follow up assessment at six months after the end of training. It shows reduction of the BBS score and the tests on comfortable gait parameters for a 10-m distance, i.e. gait speed, cadence and step length, and increase of TUGT score, which reach statistically significant level with a $p \leq 0.001$. There is no statistically significant change of fall rate.

Because there were a lot of elderly persons who were interested in the project, some of them had to wait for the training, so they did not receive training immediately after the first assessment. In such cases, they were reassessed before they received the training to make sure that the values of gait parameters and balance testing scores were updated as much as possible.

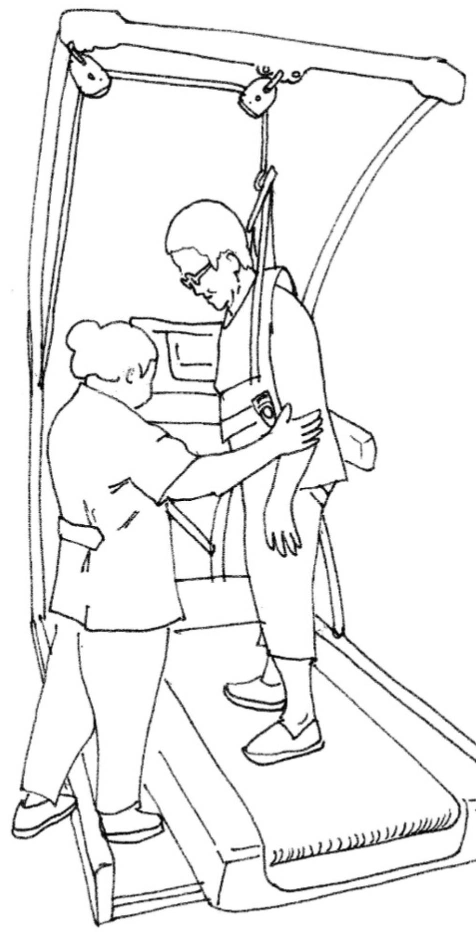

Figure 1. Elderly persons with the body weight supported treadmill training under physiotherapist supervision

Table 1. Demographic data of all 233 participants

Basic information	Number (%)
Gender	
Male	38 (16.31)
Female	195 (83.69)
Chronic diseases	
No	56 (24.03)
Yes	177 (75.97)
DM	47 (20.17)
HT	102 (43.78)
Heart	13 (5.58)
DLP	90 (38.63)
Others*	65 (27.90)

*Varicose veins, allergies, asthma, osteoporosis, bone degeneration, degenerative disc, knee osteoarthritis, gout, thyroid, acid reflux, glaucoma, benign prostatic hypertrophy, stroke, brain tumor, frozen shoulder, and breast cancer.

The participants started and finished the training at different difficulty levels according to their balance ability levels, as shown in table 5. There were 57 participants who started at step 1; 58 at step 2; 18 at step 3; 94 at step 4; 3 at step 6; and 3 at step 7. Those who started at step 1 completed the training at different steps, ranging from step 3 to step 7 and all of those who started at other steps completed the training at step 7.

Discussion

The research findings revealed that the BWSTT for fall prevention significantly improved the body balance and reduced the fall rate of the participants at a statistically significant level. This was consistent with the authors' earlier study.[17] The results were also in line with some international studies, which found that appropriate training could restore walking performance.[18] In this research, the participants' fall rate was reduced by 66.10 percent, which was more effective than that of other training methods which are reported in an extensive literature review.[14] For example, a group exercise and Tai Chi reduced the fall rate by only approximately 30 percent. The reason for the difference in their rehabilitative effectiveness may be the fact that the BWSTT was not only multidirectional balance training in the context of walking with high repetition but also changed gait speed, with starting and stopping walking. It featured balance training under external perturbation. In addition, while the participants were walking, they were talked to and asked to do another activity, e.g. receiving and throwing a ball, which was dual tasking.

In this research, the fall rate was calculated by asking the participants based on what they remembered; they were not asked to make a fall record,[19] which might result in its reduced reliability. However, the fall rate dropped significantly, by 66 percent and the body balance scores and the gait parameter values increased. Thus, this convinced that the training really provided a reduction in falls through a mechanism - improved balance. It should be noted that the balance scores and gait parameter values in this research were derived from data collected by measurement methods that were commonly used internationally and were recognized for its validity and reliability.[20,21] Besides, such improved balance and walking ability after training were in line with the finding from previous study employing similar training method, but in a hospital setting.[17]

Some limitations of this research were the fact that it was a pre-post comparative study without a control group and there were some participants who did not undergo a six months follow-up. Therefore, the future research such as a randomized

Table 2. Gait parameters and the scores of the balance tests of the participants before the training and immediately after the six weeks training (n=233)

	Unit	Before the training	Immediately after the end of the 6 weeks training	*p* value
Past 6 months fall rate	Fall/person/year	0.59 (1.49)	0.24 (1.04)	<0.001*
BBS balance score	Point	51.88 (3.96)	54.66 (2.64)	<0.001*
TUGT score	Second	11.56 (3.18)	9.89 (3.22)	<0.001*
Conformable 10-m walking speed	Kilometer/hour	3.62 (0.75)	4.31 (0.92)	<0.001*
Step length	Centimeter	53.77 (7.94)	58.15 (8.67)	<0.001*
Cadence	Step/second	112.00 (13.84)	122.62 (14.67)	<0.001*

BBS, Berg Balance Scale; TUGT, Timed Up and Go Test;
Mean (SD), *Calculated by using the Wilcoxon signed rank test

Table 3. Values of gait parameters and scores of the balance tests of the participants before the training and on the six months follow-up (n=188)

	Unit	Before the training	6 months follow-up	*p* value
Past 6 months fall rate	Fall/person/year	0.32 (0.70)	0.20 (0.67)	<0.001*
BBS balance score	Point	52.26 (3.49)	54.45 (3.27)	<0.001*
TUGT score	Second	11.10 (2.68)	9.77 (2.12)	<0.001*
Conformable 10-m walking speed	Kilometer/hour	3.70 (0.70)	4.29 (0.67)	<0.001**
Step length	Centimeter	54.61 (7.46)	58.53 (6.71)	<0.001*
Cadence	Step/second	112.78 (13.55)	122.07 (11.34)	<0.001*

BBS, Berg Balance Scale; TUGT, Timed Up and Go Test
Mean (SD), * Calculated by using the Wilcoxon signed rank test and **the paired t-test

Table 4. Gait parameters and the scores of the balance tests of the participants immediately after the six weeks training and the six months follow-up (n=188)

	Unit	Immediately after the end of the 6 weeks training	6 months follow-up	*p* value
Past 6 months fall rate	Fall/person/year	0.25 (1.12)	0.20 (0.67)	0.864*
BBS balance score	Point	54.95 (2.32)	54.45 (3.27)	<0.001*
TUGT score	Second	9.33 (2.62)	9.77 (2.12)	<0.001*
Conformable 10-m walking speed	Kilometer/hour	4.45 (0.81)	4.29 (0.67)	<0.001*
Step length	Centimeter	59.36 (7.72)	58.53 (6.71)	<0.001*
Cadence	Step/second	124.56 (13.47)	122.07 (11.34)	0.001*

Mean (SD); BBS, Berg Balance Scale;TUGT, Timed Up and Go test

*Calculated by using the Wilcoxon signed rank test

Table 5. Training difficulty levels at the start and at the end of the training (n=233)

Levels of difficulty at the start of the training	Levels of difficulty at the end of the training	Increase in the levels of difficulty	Number of participants	Percentage
1	3	2	2	0.86
1	4	3	1	0.43
1	5	4	6	2.58
1	6	5	1	0.43
1	7	6	47	20.16
2	7	5	58	24.89
3	7	4	18	7.73
4	7	3	94	40.34
6	7	1	3	1.29
7	7	0	3	1.29

controlled trial and a comparison between a trained group and a non-trained control group or a control group which undergoes other types of rehabilitation, should be conducted. Physiotherapist routinely monitor vital signs of all participants before and after each training sessions and has reported no serious adverse events during any training sessions such as falling, heart attack, syncope etc. But since no formal attempt were made to monitor and record adverse events, future study will be needed on safety could be worthwhile.

In this research, an interesting observation was that the participants who started at the step 1 finished their 12-session training at the step 3 up to the step 7, but all of those equipped with good walking and balance performance from the beginning (those who started at the step 2 or higher) finished the training at the step 7. The authors believe that this might result from the fact that those with serious balance impairment might have lower potential for walking and balance rehabilitation, or needed more time for training before they could reach a full recovery compared to those with minor balance impairment. If this assumption is true, in the future, participants with severe balance impairment should be trained more than six weeks in order to fully reduce their fall rate.

In this study, only 188 participants were contactable for the six months follow up assessment. For this reason, the number of participants and average outcome parameters are different between table 2, 3 and 4. It is possible that a significant portion of the participants lost in follow-up might have sustained a fall during the period and/or have deteriorated in their balance ability. Further study should incorporate this concern in the study design. According to experience of the authors, loss of balance ability after discontinuation of training program is very small in the first six months and becomes more pronounce afterwards, unless one has active neurological or musculoskeletal conditions. Furthermore, there should be a study on how long the training effectiveness would last after the training is completed and/or on the effects of walking training to improve the body balance and walking ability in the long run, or if long-term low repetition-training will be worthwhile by means of a health economic cost-effectiveness analysis. This will be beneficial for the consideration of scaling up the results in the future. In addition, a comparative study on the effects of the balance rehabilitation and fall prevention in elderly persons with different balance scores on health economics should be conducted in the future.

In conclusion, a biweekly 30-minute BWSTT over a six weeks period conducted by a trained physiotherapist at a local health and rehabilitation facility in community improved balance and walking ability and reduced fall rates among elderly persons with a history of falls or perceived impaired balance.

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Disclosure

Parit Wongphaet is the managing director of Tmgi.co.ltd which manufactures and sells the bodyweight support frame and harness used in this research. The treatment method is not proprietary.

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