

Comparative Effect of a Balance Training Program and Core Stabilization Program on Factors Related to the Prevention of Falling in Healthy Middle–Aged Individuals: A Double–Blind Randomized Controlled Clinical Trial

Chatwalai Sonthikul, M.Sc.¹, Wanida Kaewmune, M.Sc.¹, Porraporn Sriwannawit, M.Sc.¹, Jirapinya Kasipan, B.Sc.², Natthanan Khuatjit, B.Sc.², Duangkamol Kimakhom, B.Sc.², Pattaraporn Rueangsuk, B.Sc.²

¹Department of Physical Therapy, ²Undergraduate Student of the Department of Physical Therapy, Faculty of Medicine, Prince of Songkla University, Songkhla 90110, Thailand.

Received 12 March 2019 • Revised 17 April 2019 • Accepted 17 April 2019 • Published online 8 May 2019

Abstract:

Objectives: The aim of this study to compare the effectiveness of the balance training program (BTP), and the core stabilization program (CSP), on dynamic balance in healthy middle–aged individuals.

Material and Methods: This study was a single–blind randomized controlled trial design. Forty–two healthy middle–aged participants were randomly assigned to the BTP group (n=21), or the CSP group (n=21). Participants in both groups received an intervention program (balance training or core stabilization) 3 times a week, for 60 minutes, over 6 weeks. The primary outcome was the dynamic balance measured by the timed up and go test. The other outcomes were: core muscle endurance, muscle strength of the lower extremities, the flexibility of the lower back and hamstring muscles, and gait variables. The measurements included: the prone bridge endurance test, 5 times sit to stand test, sit and reach test and a wireless movement monitoring inertial sensor system, respectively. All outcomes were measured at baseline, and then after 6 weeks. The data were analyzed by the Independent Sample t–test between groups, and the paired t–test within either group.

Results: After 6 weeks, there was no statistically significant difference between the groups in either dynamic balance, or other variables, however, a statistically significant difference was found in core muscle endurance (p–value=0.003).

Contact: Chatwalai Sonthikul, M.Sc.
Department of Physical Therapy, Faculty of Medicine,
Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand
E–mail: chatwalai.s@gmail.com

J Health Sci Med Res 2019;37(...):.....
doi: 10.31584/jhsmr.201950
www.jhsmr.org

In so saying, the BTP group, statistically significant improvements were found only in core muscle endurance, the flexibility of the lower back and hamstring muscles, and gait variables from pre- to post-test. Moreover, in the CSP group, there was a statistically significant difference from pre- to post-test in all measured outcomes.

Conclusion: The Core stabilization program is not superior to a balance training program, for the improvement of dynamic balance. Although, after 6 weeks of training, the study found that the Core stabilization program was effective for improving dynamic balance. This finding may point out that the Core stabilization program helps improve balance in a middle-aged person

Keywords: balance training program, core strength training program, dynamic balance, gait variable, middle age

Introduction

Falling is common, and leads to fall-related injuries, which in turn result in a significant cause of morbidity and mortality in the elderly.¹⁻³ About one-third of older people, over 65 years of age, in communities have at least one experience of falling annually.^{1,4-6} Fall-related injuries consist of both minor and major injuries, with minor injuries including: bruising, lacerations, abrasions, sprains and strains. These injuries can cause noteworthy discomfort as well as pain, which affects the confidence of the elderly, and induces a fear of falling.^{1,4,7} These psychological consequences can cause self-restricted activity levels, leading to reduced functional activities, social interactions, and quality of life.^{1,4} Paradoxically, restricting activities results in a decline in physical ability; that leads to an increased risk of falling in the future.⁴ The elderly, who have a history of falling or fear of falling, increase the rate of falling to two in three for these adults.⁵ Major injuries can cause serious long-term consequences; including: head injuries and fractures^{1,4,6}, which result in long-term disability and a reduced quality of life.⁵ Fractures caused by falling were found in about 10 percent of cases, especially hip fractures^{1,4}, 15 percent died in the hospital, while a third died no more than a year afterward.²

Middle-aged individuals, who are between 40 and 65 years of age⁸, are at the starting point leading to fall-

related injuries.⁹ The incidence of falling continues to rise after middle age², due to a physiological deterioration associated with age, including: the impairment of cognitive, sensory systems, reduction in lower limb muscle strength, muscle capacity in the core muscles of the body, proprioception, joint range of motion, reaction time, and speed of movement.^{7,10,11} These changes result in worse dynamic balance, which affects the activities of daily life along with increasing the risk of falling.^{7,12,13} Therefore, effective exercise interventions for improving balance are important in order to prevent falling in middle-aged as well as older adults.³

Evidence-based guidelines suggest that exercise interventions are important for preventing falling around the world⁵, because exercise helps reduce muscle loss, increases muscle strength and endurance, improves balance and gait and also improves mood.⁵ Exercises that focus on balance, gait, and muscle strength help to reduce the rate of falling among the elderly, within the community.⁴ Based on the results of a systematic review of Gillespie et al. in 2012⁶, it was found that exercise with balance and strength training exercises can effectively reduce falling in the elderly. In addition, exercise also has a direct effect on reducing the fear of falling, or indirect effects on factors related to the fear of falling coupled with the risk of falling.⁵ However, the best exercise interventions,

for improving balance in the middle-aged population, are still unclear and include balance training and core strength training.⁷

Balance training is a basic, and popular practice for preventing falling, which is the ability to maintain the center of mass in an upright body position.¹⁴ Anderson et al. conducted a study in 2016¹⁵ in 16 middle-aged women, who were trained in balance training 3 times a week for 4 weeks, the result showed that balance training could significantly improve standing balance. The study of Nepocaty et al. in 2016¹⁶, investigated balance training on an uneven surface, 3 times per week, for 7 weeks, with 27 women, having a mean age of 40 years old. The results showed that the static balance and activities of daily life significantly improved after completing the program. However, balance training programs require training with physical therapists, or experts which can lead to wasted time and travel expenses.

Core strength training is a new exercise; that can help to improve balance in the middle-aged¹⁵, it consists of 4 main muscles; including: pelvic floor muscles, abdominal muscles, back muscles, and the diaphragm.¹⁷ These muscles act as a link to the arms and legs for the movement of the distal limbs, which affect balance, walking and daily activities.^{18,19} Anderson et al. in 2016²⁰ investigated core strength training in 16 women, aged 46.9±8.7 years old. The results demonstrated that: core strength training significantly improved in balance, and reduced body sway after completing 4 weeks of the program.¹⁵

Dynamic balance is important during ambulation, and in the activities of daily living²¹, so the best clinical practice, for the middle aged, should be quantified and requires more evidence in dynamic balance. Hence, the objective of this study was to compare the effect of the balance training program (BTP), and the core stabilization program (CSP) on: dynamic balance, core muscle endu-

rance, muscle strength in the lower extremities, flexibility of the lower back and hamstring muscles, and gait variables in a healthy, middle-aged population. We hypothesized that the CSP would improve dynamic balance, more than the BTP.¹²

Material and Methods

Trial design

A randomized controlled trial study, with a blind assessor, was conducted in a clinical setting at the university, from: January to May 2018.

Participants

Participants who were between 45 and 65 years of age, of either gender, were recruited. The inclusion criteria were: independent walking and understanding of instructions, which were necessary for the assessment and training. The exclusion criteria included a visual problem that could not be corrected with eyeglasses, limits on exercise performance due to neurological, cardio-pulmonary and musculoskeletal disorders, experience participating in regular balance training within the past 6 months, and previous experiences of falling.

Forty-two participants were eligible to be included in the study, after the initial screening. One participant, allocated to the BTP group, fell during participation in this study, and one participant, allocated to the CSP group, did not come on schedule. Two participants withdrew from the study (BTP n=1, CSP n=2) (Figure 1). No adverse events were reported.

All participants were asked to read the participant information sheet, and signed the informed consent prior to participating in this study. This study was approved by the Human Research Ethics Committee, (No. 60-433-30-2).

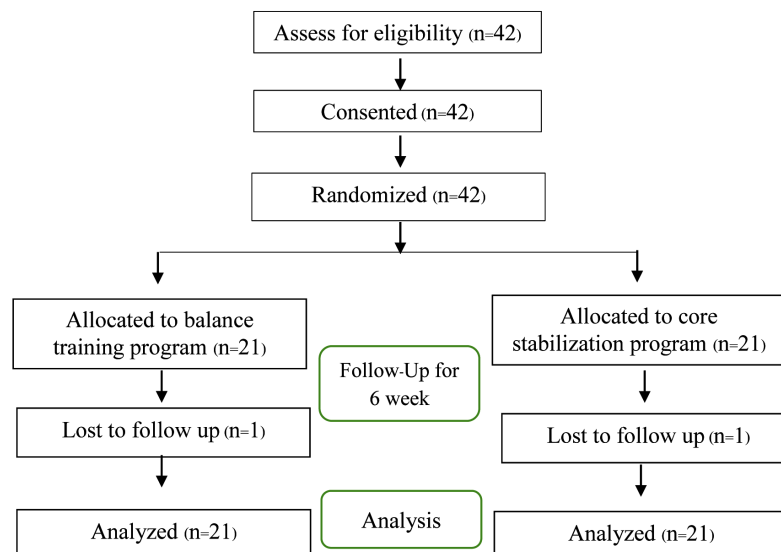


Figure 1 Flow chart diagram of the research process

Sample size

The sample size was calculated from our pilot study of 10 subjects using a formula as described

$$n_{group} = \frac{\left(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2 \left[\sigma_{CSP}^2 + \sigma_{BTP}^2\right]}{(\mu_{CSP} - \mu_{BTP})^2}$$

This study estimated on the basis of dynamic balance measured on timed up and go after six week of training and assuming 80.0% power, 5.0% of significance, and 20.0% drop out rate, to detect statistically significance between groups on timed up and go test, a minimum total sample size of 20 was required for the study.

The suitable number of participants for answering the research question was 20 for each group, Hence, 42 participants were used for the comparisons in the study.

Randomization

Participants were randomized by statistics and data (STATA) version 11. The STATA program generated a

number for randomized participants, for either the balance training program group or the core stabilization program group.

Interventions

Participants in both groups received an exercise program for 60 minutes, 3 times per week for 6 weeks. The program consisted of 20 minutes for stretching (warm up and cool down), for both groups, and 40 minutes for the balance training program or core stabilization program.

Muscle stretching consisted of 6 poses: back muscles, quadriceps muscles, hamstring muscles, gluteus maximus muscle, tensor fascia latae, and calf muscles. They stretched both before and after training, holding each pose 3 times for 15 seconds.

Balance training program

The balance training program progressed in difficulty every 2 weeks. During the 1st and 2nd week, the program consisted of: leg extensions, sideway leg lifts,

calf raises, mini squats, leg raises, and single leg stands. In the 3rd to 4th week, the program consisted of: leg extensions, sideway leg lifts, leg raises, squats, standing lift arm and leg on the opposite side, standing lift arm and leg on the same side. For the 5th and 6th weeks, the program consisted of: leg raises, lunges, standing lift arm and leg on the opposite side, standing lift arm and leg on the same side, single leg with hip internal and external rotations, and single leg squats. Each pose consisted of 10 repetitions for 1 set, with a total of 3 sets for a week, over 6 weeks for completion.

Core stabilization training program

The core stabilization training program progressed in difficulty by increasing the pose. During the 1st and 2nd week, the program consisted of: abdominal contractions, bridging, modified crunches, modified oblique crunches, side planks on the knee. The 3rd to 4th week of the program consisted of: bridging, modified oblique crunches, side lying with hip abduction, planks, side planks on the knee, and wall squats. For the 5th to 6th the program consisted of: crunches, side lying with hip abduction, planks, side planks on the ankle, and wall squats. Each pose consisted of 10 repetitions for 1 set, with a total of 3 sets for the week, over a total of 6 weeks.

All participants received logbooks, for the recording of activities of daily living and exercise, and the number of hours participating in the program per day.

Measurement outcomes

All participants were assessed before and after the programs during the 6 weeks. The outcomes consisted of: dynamic balance, core muscle endurance, lower extremities' muscle strength, the flexibility of the lower back and hamstrings, and gait variables. The measurement included: timed up and go test, prone bridge endurance

test, five times sit to stand test, sit and reach test, and a wireless movement monitoring inertial sensor system.

The primary outcome

The primary outcome was the timed up and go test, which was used for measuring dynamic balance²², with a higher time indicating greater impairment in dynamic balance. The participants started in a seated position, after which, the participants stood up upon the therapist's command, walked 3 meters, turned around, walked back to the chair and sat down again. The time was stopped when the patient sat down.²¹

Other outcomes

The other outcomes were assessed by the prone bridge endurance test, five times sit to stand test, sit and reach test, and a wireless movement monitoring inertial sensor system.

The prone bridge endurance test was used to assess the control and endurance of the back and core stabilizing muscles, with a higher time indicating greater core muscle endurance. Participants started with the upper body, supported off the ground by the elbows and forearms, with the legs straight and the weight taken by the toes. Next, the hip was lifted off the floor creating a straight line from head to toe. For each test, subjects were asked to hold the position for as long as possible, and the test was completed when the subject broke from the desired position, or displayed incorrect form and technique. The blind assessor watched the time lapse on the video recorder, and recorded time in seconds. The maximum time was used for analysis.²³

Five times sit to stand was used to assess the lower limb muscle strength. This test is quick and easy, and has a high inter-rater and intra-rater²⁴, with a lower time indicating greater lower limb muscle strength. The

participants were asked to stand up and sit down five times as fast as possible, without using their hands to push up from the chair. Timing begins at “go” and ends when the buttocks touches the chair, after 5 repetitions. The assessor watched the time lapse on the video recorder, and recorded time in seconds. The maximum time was used for analysis.²⁵

The sit and reach test was used for measuring the flexibility of the lower back and hamstring muscles. A higher distance indicated greater flexibility of the lower back and hamstring muscles. Participants sat on the floor with legs stretched out, feet placed flat against the box. With hands on top of each other, the participant reaches forward along the measuring line as far as possible, ensuring that the hands remain at the same level, not one reaching further forward than the other. After some practice reaches, the participant reaches out and holds that position for two seconds while the distance is recorded.²⁶

Gait variables were measured using a wireless movement monitoring inertial sensor system (APDM Inc., Portland, OR, USA).²⁷ After recalibration, four synchronized opal inertial sensors were fitted on each participant, via elastic straps (sternum, waist at the level of the fifth lumbar spine, and ankle of each foot). Each participant was instructed, “Start walking naturally and continue to the end of walkway”. Signals were sent to a laptop automatically, which were processed and calculated via the corresponding Mobility Lab™ software package. The gait velocity and stride length were chosen for analysis.²⁸

Data analysis

Data were analyzed using the Statistical Package for the Social Sciences 21 for windows. The normal distribution of data was analyzed by a Kolmogorov–Smirnov Z test. Continuous data are given as mean and standard

deviation, while, discrete data are given as frequency counts and percentages. The analysis was by intention to treat. For participants lost to follow up, we conservatively assumed that the values at the 6 weeks were identical to those before training. The Independent Samples t-test and chi-square test were used to compare both demographic characteristics and baseline parameters between the two groups. Comparisons of all parameters, between pre- and post-training within a group, were analyzed using a paired t-test. In order to investigate different change values (subtracting the pre-training data from the post-training data) between the BTP and the CSP groups, Independent Samples t-test was used. Statistically significant differences for all analyses were set at $p\text{-value} < 0.05$.

Results

There was no significant difference in the baseline data, or parameters between the groups (Table 1).

There was no statistically significant difference between the groups in the timed up and go test, however the study found a statistically significant difference in the prone bridge endurance test ($p\text{-value} = 0.003$), after completing the program. However, the BTP and CSP groups showed significant changes from pre- to post-tests, within their respective group (Table 2).

In the BTP group, there were increasing, significant improvements in the prone bridge endurance test ($p\text{-value} < 0.001$), sit and reach test ($p\text{-value} = 0.008$), stride length ($p\text{-value} = 0.034$) and gait velocity ($p\text{-value} = 0.038$). In the CSP group, there were significant improvements in the timed up and go test ($p\text{-value} < 0.001$), prone bridge endurance test ($p\text{-value} < 0.001$), five times sit to stand test ($p\text{-value} = 0.002$), sit and reach test ($p\text{-value} < 0.001$), stride length ($p\text{-value} = 0.002$) and gait velocity ($p\text{-value} = 0.003$).

Table 1 Demographic characteristics of study participants

Parameters	Balance training program group (n=21)	Core stabilization program group (n=21)	P-value
Gender ^a			
Male	8 (38.0%)	10 (47.6%)	0.573
Female	13 (62.0%)	11 (52.4%)	
Age (years) ^b	56.74±4.36	57.28±4.75	0.635
Body mass index (kg/m ²) ^b	24.31±2.38	24.82±3.35	0.644
Waist circumference (cm) ^b	85.95±6.13	86.23±9.56	0.921
Timed up and go test (sec) ^b	6.93±1.22	6.76±0.75	0.236
Prone bridge endurance test (sec) ^b	27.68±17.32	35.15±20.23	0.118
Five time sit to stand (sec) ^b	6.47±2.26	7.23±2.15	0.427
Sit and reach test (cm) ^b	9.27±7.91	9.23±5.06	0.107
Stride length (cm) ^b	113.21±18.73	118.33±11.60	0.197
Gait velocity (cm/sec) ^b	117.10±14.70	122.98±17.92	0.112

^aFrequency counts (percentage), test statistically by the chi-square test^bMean±standard deviation, test statistically by Independent Samples t-test**Table 2** Comparisons of parameters between pre- and post-training in the Balance training program (n=21), and Core stabilization program (n=21) groups, and changes in score between the groups

Parameters	Value ^a				Change value ^b	
	Balance training program group (n=21)		Core stabilization program group (n=21)		Balance training program group (n=21)	Core stabilization program group (n=21)
	Before	After	Before	After	After-before	After-before
Timed up and go test (sec)	6.93±1.22	6.66±0.75	6.76±0.75	6.23±0.74**	-0.27±0.78	-0.54±0.49
Prone bridge endurance test (sec)	27.68±17.32	45.37±25.83**	35.15±20.23	76.84±33.68**	17.89±14.42	41.94±30.74**
Five time sit to stand (sec)	6.47±2.26	5.93±2.65	7.23±2.15	5.86±1.48**	-0.54±1.29	-1.40±1.11
Sit and reach test (cm)	9.27±7.91	11.13±9.26**	9.23±5.06	12.69±7.75**	1.98±1.85	3.47±1.57
Stride length (cm)	113.21±18.73	118.87±10.20*	118.33±11.60	125.48±9.84**	5.05±9.43	7.84±8.76
Gait velocity (cm/sec)	117.10±14.70	123.65±14.38*	122.98±17.92	133.18±17.23**	5.78±14.72	10.98±19.84

^aMean±standard deviation, *p-value<0.05, **p-value <0.01 by the paired t-test^bMean±standard deviation, *p-value<0.05 by the Independent Samples t-test

Discussion

This study was a single-blind randomized controlled trial in order to eliminate assessor bias. According to individual logbook data, participants did not undertake any other activity that might interfere with the 6-week training program, such as exercise. Thus, any improvement observed during the study is likely to result from the training program.

This study found that CSP revealed a significant improvement in the prone bridge endurance test, compared to BTP, this is also supported the previous study²⁹, which compared core muscle strength training and balance training, after 8 weeks in 26 teenagers. That study found a significant improvement in core muscle strength after measuring by using isometric maximum voluntary back extension testing. These might be caused by the mechanism of using the pose in the CSP group for assessment of a specific training task, if so then related CSP values received would be stratified as better than the related BTP values.

This study found no significant improvement in the timed up and go test in the BTP group, again this result is supported by the previous study³⁰, which also found no significant increase in the timed up and go test, after balance training for 12 weeks, in the elderly. In regards to the mechanism occurring afterwards, participants in this study had no balance problem, and the program might not have been an ample challenge for this group. There was a significant improvement in the prone bridge endurance test, sit and reach test, stride length, and velocity in the BTP group. These changes were the result of the training program. Participants needed to stand and move extremities to train coordination of core muscles for postural control. That can help to increase core muscle endurance. Furthermore, if the postural control is improving, participants would be able to increase stride length along with increasing gait velocity. From the study of Donath et al. in 2015³¹,

they found a significant increase in core muscle endurance after balance training, 2 times a week, for 8 weeks in the elderly. From the study of Taylor-Piliae et al. in 2006³², they found a significant increase in sit and reach after Tai-chi, 3 times a week, for 12 weeks in the age range of 57.4 to 74 years old. Inconsistently, from the study of Beling et al. in 2009³⁰, no significant improvement in gait velocity was found after balance training, 3 times a week, for 12 weeks in 11 participants, who had a risk of falling.

There were significant improvements in the prone bridge endurance test, sit and reach test, five times sit to stand test, timed up and go test, stride length, and velocity in the CSP group. Some poses; such as, the plank, bridging, wall squat, and side plank encourage core and proximal muscle strength.³³ It was found that the strength of the core and lower limb muscles increased when the muscle group acts as a link to the arms and legs, causing the stability of the proximal to be used for the movement of the distal limb, which in turn affects balance and walking.^{18,19} From the study of Aggarwal et al. in 2010³⁴, they found a significant increase in core muscle strength after core strength training, 3 times a week, for 6 weeks when measured using the prone plank test, in the age range of 18 to 27 years of age. From the study of Mohammadi et al. in 2015³⁵, they found a significant increase in lower limb muscle strength after Pilates when measured using the 30-second chair stand test in 30 elderly women. From the study of Sekendiz et al. in 2010³⁶, they found a significant increase in sit and reach after core balance training with a Swiss ball, 3 times per week, for 12 weeks in women with low physical activity and in the age range between 25 to 42 years old. They found a significant increase in dynamic balance after 6 weeks when measured using the timed up and go test, after core strength training in 10 patellofemoral osteoarthritis.³⁷ Additionally, from the study of Newell et al. in 2012³⁸, they

found a significant increase in stride length and gait velocity after Pilates training, 1 time a week, for 8 weeks in 9 elderly people.

The core muscles support the spine for balance, which requires motor control, especially deep muscles, such as multifidus and transversus abdominis, and a combination with the superficial muscles; such as, rectus abdominis, obliques, erector spinae, and quadratus lumborum muscles.³⁹ It was found that the strength of the core muscles was important in daily activities. The elderly, with core muscle weakness, undergo reduced daily activities within 3 years.⁴⁰ Increased core muscle endurance results in an increase in the activities of daily life.

None of the participants fell during the training program. Thus, our protocol was safe and suitable for healthy, middle-aged people.

There are limitations of this study that should be addressed: No long-term follow-up of training. Further studies should investigate the effects of the programs in the long term.

Conclusion

Only the core stabilization program could improve dynamic balance in healthy, middle-aged individuals, but a balance training program might not be appropriate for improving dynamic balance in this group. Moreover, core stabilization training is more effective than the balance training program in terms of increasing core muscle endurance. However, both programs had a beneficial effect in improving core muscle endurance, the flexibility of the lower back and hamstring muscles, stride length and gait velocity.

Acknowledgement

This study was supported by the Faculty of Medicine, Prince of Songkla University.

Conflict of interest

There are no conflict of interest.

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