ผลของการฝึกทรงตัวด้วยอุปกรณ์ที่พัฒนาจาก passive infrared sensor ในผู้ป่วยโรคหลอดเลือดสมอง

EFFECT OF BALANCE TRAINING BY A DEVICE DEVELOPING FROM PASSIVE INFRARED SENSOR IN STROKE PATIENTS

THIPWIMON SILLAPACHAI

GRADUATE SCHOOL Srinakharinwirot University

2018

ผลของการฝึกทรงตัวด้วยอุปกรณ์ที่พัฒนาจาก passive infrared sensor ในผู้ป่วยโรคหลอดเลือดสมอง

ทิพวิมล ศิลปชัย

ปริญญานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตร
วิทยาศาสตรมหาบัณฑิต สาขาวิชากายภาพบำบัด
คณะกายภาพบำบัด มหาวิทยาลัยศรีนครินทรวิโรฒ
ปีการศึกษา 2561

EFFECT OF BALANCE TRAINING BY A DEVICE DEVELOPING FROM PASSIVE INFRARED SENSOR IN STROKE PATIENTS

THIPWIMON SILLAPACHAI

A Thesis Submitted in partial Fulfillment of Requirements

for MASTER OF SCIENCE (Physical Therapy)

Faculty of Physical Therapy Srinakharinwirot University

2018

THE THESIS TITLED

EFFECT OF BALANCE TRAINING BY A DEVICE DEVELOPING FROM PASSIVE INFRARED SENSOR IN STROKE PATIENTS

BY

THIPWIMON SILLAPACHAI

HAS BEEN APPROVED BY THE GRADUATE SCHOOL IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTER OF SCIENCE IN PHYSICAL THERAPY AT SRINAKHARINWIROT UNIVERSITY

-- Dean of Graduate School

(Assoc. Prof. Dr. Chatchai Ekpanyaskul, MD.)

ORAL DEFENSE COMMITTEE

.... Major-advisor

(Asst. Prof.Saitida Lapanantasin, Ph.D.)

.... Chair

(Asst. Prof.Wasuwat Kitisomprayoonkul, M.D.)

.... Committee

(Assoc. Prof.Rumpa Boonsinsukh)

Title	EFFECT OF BALANCE TRAINING BY A DEVICE DEVELOPING FROM PASSIVE INFRARED SENSOR IN STROKE PATIENTS
Author	THIPWIMON SILLAPACHAI
Degree	MASTER OF SCIENCE
Academic Year	2018
Thesis Advisor	Assistant Professor Saitida Lapanantasin , Ph.D.

Background: After an individual suffers a stroke, intrinsic feedback systems may be destroyed and resulted in difficulty to adjust postural control and balance. Therefore, providing extrinsic feedback may help stroke patients to relearn how to effectively adjust their movements. This study aimed to develop a balance training device with auditory feedback from passive infrared sensors and investigated the effects of training using the developed device on balance performance in subacute strokes. *Methods:* Twenty four subacute stroke patients aged forty-five to sixty-five years with asymmetrical weight bearing on the affected leg in standing < 40% of body weight were recruited. They were randomly assigned to either the experimental (n=12) or the control (n=12) groups. The experimental group received a conventional rehabilitation program of thirty minutes and balance training using a developed balance training device with auditory feedback from a passive infrared sensor for thirty minutes. The control group received only a conventional rehabilitation program for one hour per session. Both groups were enrolled in their training for five sessions per week for four weeks. The balance performances of all patients were assessed using the Berg balance scale (BBS), a functional reach test (FRT), timed up and go test (TUG), and a percentage of weight bearing on the affected leg (%BW) before and after four weeks of training. *Results:* After training, BBS, FRT, TUG and %BW were significantly improved in comparison to the baseline for the experimental group (p<0.05), while the control group only demonstrated a tendency for BBS improvement. Additionally, the experimental group demonstrated significantly better improvements in BBS, TUG and %BW than the control group (p<0.05). *Conclusion:* The balance training program by using balance training devices developed from PIR sensors combined with conventional rehabilitation program can improve the balance performance of subacute stroke patients more effectively than conventional rehabilitation.

Keyword : Stroke, Balance, Auditory feedback, Infrared sensors

ACKNOWLEDGEMENTS

I would like to thank everyone who helped and supported this research to accomplish successfully. Foremost, I would like to express my sincere gratitude to my research advisor, Assistant Professor Saitida Lapanantasin who is kindly supportive throughout the study period in Master of Science Physical Therapy at Srinakharinwirot University.

In addition, I would like to thank Miss Jittima Charoenlimprasert (Head of Physical Therapy Division, Thai Red Cross Rehabilitation Center who assessed the participants in this study. I also thank all participants who were interested and cooperative. Furthermore, I would like to thank the Thai Red Cross Rehabilitation Center for providing a research setting place.

Finally, I would like to thank for the research grants from the project "Capacity Building Program for New Researcher 2018" of National Research Council of Thailand (NRCT). Also, I appreciate the staffs of the Graduate School of Srinakharinwirot University for providing good coordination with the NRCT.

THIPWIMON SILLAPACHAI

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

CHAPTER 1
INTRODUCTION

Background

Postural control requires the collaboration of multiple physiological systems including of biomechanical constraints, cognitive processing, verticality perception, movement strategies, and sensory integration and reweighting(Shumway-Cook & Woollacott, 2001). So, the physiological system impairments will result in postural control problems. The sensory systems contributing to postural control consist of visual, vestibular and somatosensory. An integration of information from these systems, which feedbacks to adjusting the body position in relation to gravity, support surface, and environment, is essential for postural control(de Oliveira, de Medeiros, Frota, Greters, & Conforto, 2008).

The sensory feedback is an important information for promoting motor learning in balance control. For example, the reduced balance performance in some elders or some people with neurological problems is due to a lack of sensory inputs from malfunction of the visual, vestibular or proprioceptive systems(Day, Guerraz, & Cole, 2002). Moreover, postural instability problem often leads to an increase in risk of fall, disability and limitation in daily living activities as well(Nyberg & Gustafson, 1995; Sawacha et al., 2013). However, in many cases, loss of peripheral sensory information is irreversible, the brain can learn how to compensate for the sensory information loss by relying more information on the other sensory channels(Corriveau et al., 2000).

Feedback can be classified into “intrinsic feedback” and “extrinsic feedback”. The intrinsic feedback or inherent feedback is a sensory-perceptual information of its own that is a result of movement. The extrinsic feedback or augmented feedback which often comes from external sources is a feedback that adding to intrinsic feedback. Extrinsic feedback can be divided into “knowledge of results” (KR) and “knowledge of performance” (KP)(van Vliet & Wulf, 2006). KR is an external information presenting the effect of making a skill or about the fulfillment of the performance. KP is an external data about the movement description that leads to a performance of results. Moreover, the feedback can be classified according to the sources such as verbal feedback, visual feedback, vibrotactile feedback, and auditory feedback.

After stroke, intrinsic feedback systems may be destroyed and resulting in a difficulty to determine how to adjust a performance. Previous studies showed that patients with unilateral stroke were able to learn a new motor skills(Magill & Anderson, 2017; Winstein, Merians, & Sullivan, 1999). Therefore, providing extrinsic feedback may be even more important for stroke patients to relearn how to adjust the movements in the most effective way.

The effect of weight shifting training on postural control during quiet standing in patients with stroke was previously investigated and found that it was able to improve the postural control such as center of pressure (CoP) displacement, CoP velocity, and movement time(Hanlon, 1996). Moreover, the previous studies convinced that stroke patients were improved postural control in sitting, sit to stand, and standing by balance training devices providing with either extrinsic visual or auditory feedback during weight shifting or weight distribution training(Cheng, Wu, Liaw, Wong, & Tang, 2001; de Haart, Geurts, Dault, Nienhuis, & Duysens, 2005; Jung, Kim, Chung, & Hwang, 2014; Mudie, Winzeler-Mercay, Radwan, & Lee, 2002; Tsaklis, Grooten, & Franzen, 2012). Sinceauditory or visual feedback from the devices allowed information about postural control which helped to supplement the intrinsic feedback. However, the balance training devices are large, expensive and difficult to move. Thus, the research related to develop an inexpensive portable balance training device will be valuable and interesting.

A passive infrared sensor (PIR sensor) is a motion detecting sensor. It's small, portable, and affordable price. The sensor detects the change of infrared radiation emitted from a thing as moving passes the sensor. When the circuit receives heat from the infrared radiation would then be converted into an electrical signal and produces a sound. Therefore, a purpose of the study is to develop a balance training device by applying the PIR sensor to produce an auditory feedback, as KR, for the weight shift training to improve balance of stroke patients.

Research Question

Is an application of the developed balance training device with auditory feedback from passive infrared sensor (PIR) able to improve postural control in patients with stroke?

Objectives

General Objective

To investigate the effect of balance training by using the developed balance training device with an auditory feedback from passive infrared (PIR) sensors.

Specific objectives

1. To compare balance performance in person with stroke between pre- and post-training by using the developed balance training device with an auditory feedback from passive infrared(PIR) sensors

2. To compare the changes of balance performance at post-training between person with stroke that using the developed balance training device with an auditory feedback from passive infrared (PIR) sensors and the control that without using the device.

The parameters representing balance performance for this research includes of the berg balance scale, functional reach test, timed up and go test, and percentage of weight bearing on affected side.

Hypothesis

Balance training by using the developed device with auditory feedback PIR sensor will improve the postural control of the persons with stroke.

Expected Benefits & Application

1. The research results will provide the information for the further studies related to balance training in strokes.

2. The developed device with auditory feedback will be a useful portable balance training device with affordable price for persons with stroke.

Definition of Terms

1. **Stroke** is characterized as a neurological deficit and injury of the central nervous system (CNS) by vascular causes including intracerebral hemorrhage, cerebral infarction, and subarachnoid hemorrhage.

2. **Postural control** is the ability to control the body's position in space for the dual purposes of orientation and stability.

3. **Limits of stability** is the greatest distance in any directions that a person can tilt the body away from a midline vertical position without falling, stepping, or reaching for support.

4. **Auditory feedback** is the sound information from loudspeaker that shown the expected goal.

Keywords

Stroke, Balance, Auditory feedback, Infrared sensor

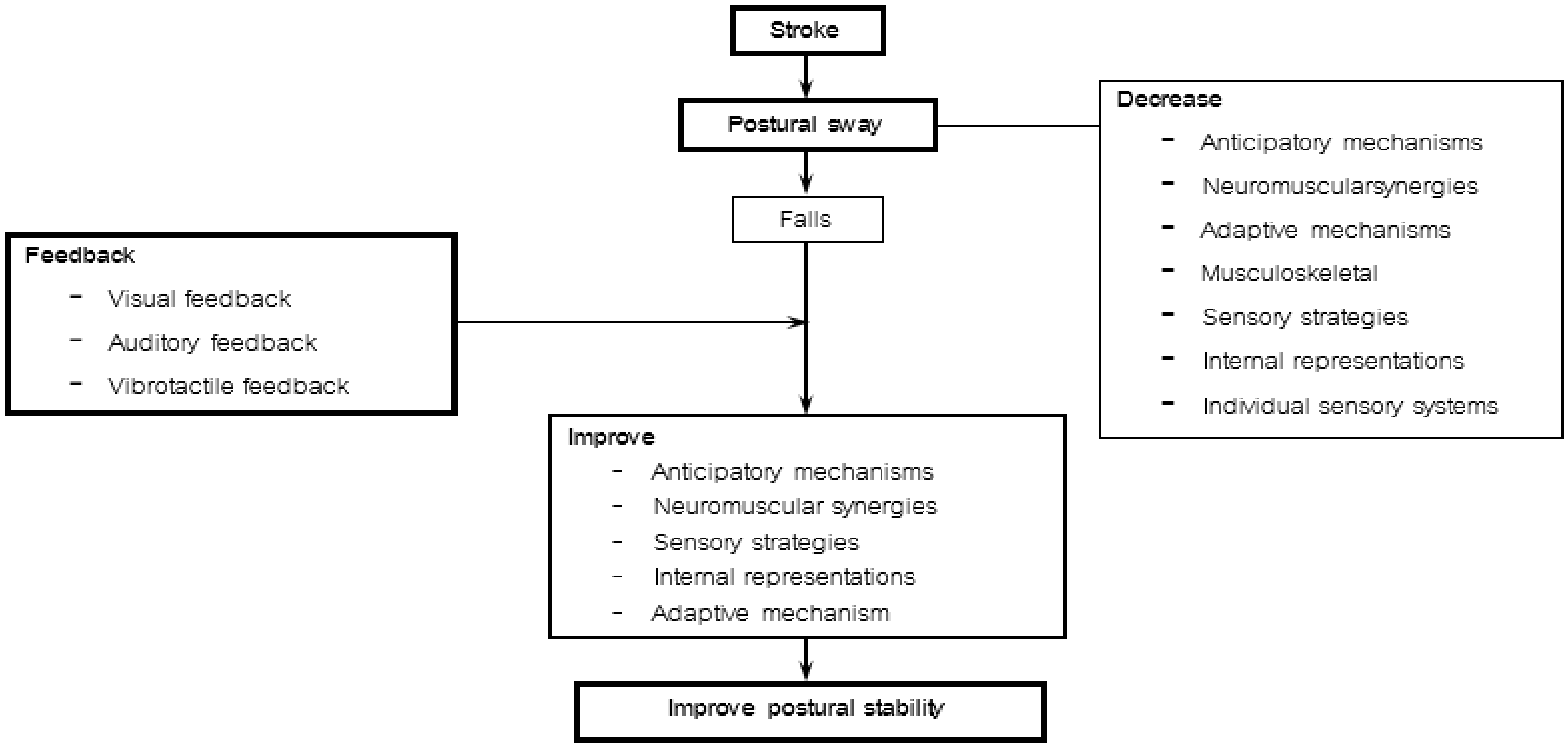


Figure 1 The conceptual framework of this study

CHAPTER 2
THE LITERATURES REVIEW

The review of literatures is divided into 5 parts as follows.

1. Stroke and the problems of postural control
2. Feedback and learning
3. Balance training by using devices
4. Passive infrared sensor
5. Balance assessment for stroke patients
6. Weight bearing assessment

1. Stroke and the problems of postural control

Stroke is vascular injury, including ischemia, infarction, and hemorrhage in the Central Nervous System (CNS)(Sacco et al., 2013). After stroke, the brain is unable to execute properly that resulting in many problems. For example: lack of motor control, sensory impairment and deficit in maintaining balance(De Weerdt & Harrison, 1985).

Persons with stroke often demonstrate a difficulty in controlling the posture. Postural control desires the interaction of many physiological systems including of biomechanical constraints, cognitive processing, perception of verticality, movement strategies, sensory integration and reweighting and sensory modalities. So, the postural control problem can be caused by any impairments of those systems. Moreover, the postural control deficit in person with stroke usually results in a risk of falls.(Tutuarima, van der Meulen, de Haan, van Straten, & Limburg, 1997)

Biomechanical constraints

Postural control is an ability to maintain the center of mass (CoM) to stay in the base of support (BoS).The position of the CoM is not fix all the time, whereas it can be changed as the body moves and even as in quiet standing. In quiet stand, the position of the CoM is in front of the L2. When the trunk leans forward, the position of CoM is moving more towards to the front. The most far distance that CoM displaces without moving the feet and still keeping in stability is called “limit of stability”. Biomechanical constraints can influence on limit of stability such as restricted range of motion, and abnormal muscle tone, strength or control. Stroke patients often have muscle weakness and motor control impairment as a result to reduce the postural control ability.

Cognitive processing

Postural control is influenced by sensory feedback and also by expectation, attention, experience, intention, and environmental context. . Inadequate attention that usually happened in stroke patients can lead to postural instability and risk to falls, particularly in complicated or more difficult tasks.

Perception of verticality

Normal persons are able to identify gravitational verticality within 0.5° without using visual feedback. In stroke patients, perception of body posture in relation to gravity is altered(de Oliveira et al., 2008). The persons with stroke, who have visuospatial neglect condition resulting in abnormal of visual verticality, commonly sit tilted to the non-paretic side. On the other hand, some persons with stroke who have a “pushing” or “pusher syndrome” always sit tilted to the paretic side. The tilted posture or asymmetrical alignment from impaired verticality perception in person with stroke will lead to instability of postural control either in static or dynamic balance.

Movement strategies

There are three patterns of body movement responding to maintain balance that are ankle, hip, and step strategies. The ankle strategy is a reaction for keeping the trunk in a vertical position when person receive a small perturbation while standing. Then, if balance is more disturbed, the ankle strategy will be not enough to justify and the hip strategy will be executed for maintaining balance. The ankle and hip strategies are “in-place strategies” which able to maintain balance without changing a base of support. In case, the greater and faster perturbations make the center of mass moved away from the original, the movement reaction will be changed to make a new appropriate base of support. The base of support can be done faster and more by stepping the foot. This pattern is called a stepping strategy.

Sensory modalities and integration

Sensory systems affect to postural control consist of visual, vestibular and somatosensory. Integration of information from these systems is crucial for postural control that adjusts the position of the body in relation to the environment, gravity, and support surface. The visual system provides information about the position and movement of the body when compare with the environment. Somatosensory system including the feeling on the skin, muscles and joints provides information about the position and movement of the body compared to the rest of the body and compared to the support surface. Vestibular system serves to recognize the gravity and provides information about the movements of the head respectively to the gravity. While standing on firm surface, central nervous system (CNS) receives information from somatosensory system 70%, Vestibular system 20% and visual system 10%(Peterka, 2002).However, if standing on an unstable area that interfere somatosensory system so will get more information from the vestibular and visual system.

2. Feedback and learning

The feedbacks can enhance motor learning. During training, the performer uses feedbacks to detect errors of the performance by comparing with the expected goal. Then he/she improves the performance in the next time planning, attentional, and focus on practice. As a result, increasing the effectiveness of training by learning from the feedbacks. The feedbacks can be classified into "intrinsic feedback" and "extrinsic feedback". The intrinsic feedback (or Inherent feedback) is a person's own sensory-perceptual information that is available as a result of movement being performed. The extrinsic feedback (or augmented feedback) is a feedback from external sources that given in addition to intrinsic feedback(van Vliet & Wulf, 2006).

Extrinsic feedback can be classified into "knowledge of results" (KR) and "knowledge of performance" (KP). KR is "externally presented information about the outcome of performing a skill or about achieving the goal of the performance". KP is "information about the movement characteristics that led to the performance outcome"(Magill & Anderson, 2017). Furthermore, feedback can be classified according to the sources such as verbal feedback, visual feedback, vibrotactile feedback, and auditory feedback. Therefore, the inaccurate or inadequate of sensory feedback information from vestibular, somatosensory, and visual systems will diminish a balance performance. In many cases, the loss of peripheral sensory information is not curable or reversible, the brain can compensate for the loss of sensory information by relying more on the other sensory channels.(Corriveau et al., 2000; Dozza et al., 2005) After stroke, intrinsic feedback systems may be impaired, making it difficult for the person to determine what needs to be done to improve performance. Extrinsic feedback may thus be even more important to people with stroke. Studies have shown that patients with unilateral stroke are able to learn new motor skills.(Hanlon, 1996; Winstein et al., 1999) The role of the therapist is to provide feedback that is likely to assist learning in the most effective way. Feedback is probably delivered intuitively much of the time during stroke rehabilitation.

The previous study in stroke subjects investigated the socio-affective characteristics of extrinsic feedback by physiotherapist. Patient-physiotherapist interactions were videotaped and then subjected to systematic observation, in which behaviour was recorded into pre-determined categories of verbal and physical communications. This study found that verbal feedback was used extensively by physiotherapists and was used more frequently than visual feedback.(Talvitie, 2000)

Moreover, the previous studies demonstrated that stroke patients received benefit from visual feedback about weight distribution and weight shift activity. The researcher found significant improvements when compared a visual feedback group to a control group in the aspect of stance symmetry and sway, motor function and activities of daily living after 4-week training. The training program was that patients received visual feedback on a computer screen while attempting balance tasks on a balance platform. These changes presented at 4 weeks after the intervention, but not at 12 weeks(Sackley & Lincoln, 1997). In a similar study in which visual feedback was given about center of gravity to more acute stroke patients, balance performance also improved but was not significantly different from a group receiving the same amount of balance training via the verbal and tactile cues which more typically used in physiotherapy(Walker, Brouwer, & Culham, 2000).

Auditory feedback of force production was also shown to improve performance of the sit-to-stand movement. At the end of a 5-week program of daily practice of sit to stand, the experimental group receiving ground reaction force feedback via auditory input achieved significantly greater symmetry in body-weight distribution than the control group(Engardt, Ribbe, & Olsson, 1993). Portable weight distribution auditory feedback devices have been employed also(Batavia, Gianutsos, & Kambouris, 1997). One study evaluated the effect of such a device on performance of sit-to-stand(Fowler & Carr, 1996). A small group of patients receiving auditory feedback during practice of sit-to-stand for a period of 3 weeks were compared to a control group who underwent the practice without the feedback. The results were equivocal although there was a tendency for the feedback group to increase force production through the affected lower limb more than control subjects.

Dursun et al. in 1996 also demonstrated positive effects for an angular biofeedback device for sitting balance. The device was positioned on the midline of the back, and gave information about tilting from the erect position with feedback given both by visual and auditory signals. Balance performance was significantly better on some of the measures used, compared to the control group, after10 days of treatment, but the difference was not maintained at discharge.(Dursun, Hamamci, Donmez, Tuzunalp, & Cakci, 1996)

There are other instrumental forms of feedback under development for stroke rehabilitation, such as virtual reality-augmented training. For example, the patient can wear different types of gloves containing infrared sensors and force transducers while attempting upper limb movements one for monitoring amplitude, speed and fractionation of movement, the other, a force feedback glove, monitoring strength of finger flexion and extension movements. Online visual, auditory and force feedback was provided via a personal computer. Exercises were in the form of imaginative computer games with graphics feedback and goals were set according to ability. One and a half hours of virtual reality training plus practice of fine motor tasks, spread over a period of 3.5 hour per day for 2 weeks, was found to have good effects.(Jack et al., 2001; Merians et al., 2002)

3. Balance training by using devices

The problems in standing balance of stroke patients can be solved in several ways. Whether using the device or without the device. At present, there are several new devices or tools for balance training in patients with stroke. These devices showed an influence on the balance improvement for stroke patients. The devices that used in training was created or invented under different theories.

Lee and co-workerin1996 studied the effect of Biofeedback Training Device on standing balance of patients with stroke. Sixty participants with mean age 49.12 ±15.15 years were randomly divided into two group (control and experimental).Control group was trained by traditional standing training table. Experimental group was trained by new weight-bearing biofeedback training devices. Each patients was trained twenty minutes per session, five sessions per week for a period of three to four weeks. After training for three weeks, the percentage of patients with Standing Steadiness Index (SSI)<10% for control group increased from 26% to 62% and 43% to79% for the experimental group. After training for four weeks, control group and experimental group have reduced of SSI to 10.1 ± 6.4% and 3.5 ± 2.2%, respectively ($p<0.02$)(Lee, Wong, & Tang, 1996).

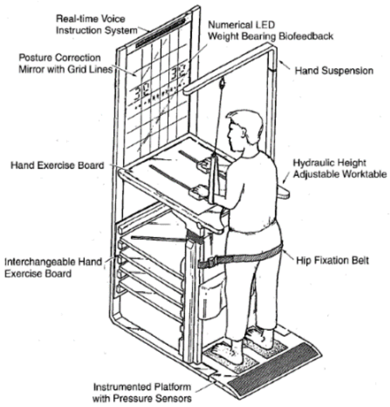


Figure 2 New weight-bearing biofeedback training devices(Lee et al., 1996)

The effect of Oswestry Standing Frame was studied by Bagley P. and co-worker in 2005. One hundred and forty stroke patients with mean age 75.5 ± 10.5 years were randomly divided into two group (control and experimental).The control group received general training without standing frame. The experimental group was trained by Oswestry Standing Frame. However, the scores of Rivermead Mobility Index, Barthel Index, Trunk Control Test, Rivermead Motor Assessment, and Motor Assessment Scale in balance sitting and sitting to standing did not different between the two groups after completion of training.(Bagley, Hudson, Forster, Smith, & Young, 2005)

Figure 3 Oswestry Standing Frame

http://www.oswestry-frames.co.uk/

Goljar and co-worker in 2010 investigated the effect of using a Balance Trainer on standing balance. They compared the effect of Balance Trainer with conventional balance training program in subacute stroke patients (mean age 61 ±8.9 years). Both groups have been practicing for twenty minutes per day, five days per week for four weeks. The results after training found that scores of the Berg Balance Scale, Timed Up and Go, 10 m walk were much better ($p < 0.001$, $p < 0.001$, $p = 0.001$, respectively) in both groups. Moreover, each group needs less help from a physical therapist significantly for standing balance ($p = 0.016$).(Goljar, Burger, Rudolf, & Stanonik, 2010)

Song and co-worker in2014studied the effect of Virtual Reality (VR) and Tetra-Ataxiometric Posturography Programs (Tetrax) in thirty patients with stroke. The patients had mean age 62.47 ± 15.17years and were randomly divided into three group (Virtual reality, Tetrax, and control group). Each group recieved conventional balance training twenty-five minutes per session, five sessions per week. While, the virtual reality group will be added virtual reality treatment and tetrax group will be added tetrax treatment 25 minutes per session, three sessions per week for three weeks. The results of training showed that, the Berg Balance Scale and the Falling Index were much better in all groups ($p < 0.05$). In open-eyed position, the virtual reality group presented much improvement in the Stability Index and Weight Distribution Index ($p<0.017$). In closed-eyed position, Tetrax group had much better either the Stability Index or Weight Distribution Index ($p<0.017$).(Song et al., 2014)

Figure 4 The Virtual Reality (VR)(Song et al., 2014)

Figure 5 The Tetra-AtaxiometricPosturography Programs (Tetrax)(Song et al., 2014)

Furthermore, the Nintendo Wii game was used for training standing balance in the stroke patients. Gonzalez-Fernandez and co-workers in 2010investigated the effects of balance practice by Wii game in stroke patients (duration time more than eight months) aged 45-76 years. They compared the results between the Wii game group and control group that received general balance training program. The Wii game group was instructed to bend or tilt the body in different directions to move the cursor on a specific target. After training, the Wii game group increased the score of Berg Balance Scale ($p = 0.002$) but the control group did not change ($p > 0.05$).(Gonzalez-Fernandez, Gil-Gomez, Alcaniz, Noe, & Colomer, 2010) Qicheng Ding and co-worker in 2012. Applied a Wii game to practice the stroke patients aged 55-78 years and onset 8-78 months ago. They compared the results of the experimental group that received Wii game and the control group that received aerobic exercise and muscle strength training. The experimental group was trained by standing on the Wii balance board, then bend or tilt to control of the ski. After training for five times, COP results showed that the experimental group had COP tracking error lower than in the control group ($p < 0.05$).(Ding et al., 2013) While, Ki Hun Cho and co-worker in 2012 used Wii game to trained stroke patients age 64.16 ± 7.61 years that had onset more than six months. The experimental group played the balance bubble, ski slalom, ski jump, soccer heading table tiling and penguin slide. The results were compared with control group that received physical therapy, occupational therapy and speech-language therapy. Each patient was trained thirty times. They found that the Postural sway, Berg Balance Scale (BBS), Timed Up and Go test (TUG) of both groups has not changed ($p>0.07$). BBS and TUG of the experimental group increased more than control group ($p<0.05$).(Cho, Lee, & Song, 2012) Other than, the patients with stroke (onset 3 months) aged 63.6$\pm$14.7 years were trained with Wii game by Kelly J. Bower and co-worker in 2014. The control group was received physical therapy, occupational therapy and Wii game in upper limb. The experimental group received Wii balance board training either static or dynamic activities. After training, the results were compared between two groups. The Step Test, Functional Reach (FR), Timed Up and Go test (TUG), and STREAM do not differences between the two groups. However, the experimental group revealed an improvement of the TUG ($p=0.023$), STREAM ($p=0.022$), and Step Test ($p=0.004$).(Bower, Clark, McGinley, Martin, & Miller, 2014)

Figure 6 The patients was trained about Wii game in ski slalom program.

4. Passive infrared sensor

Motion sensor is the device that transforms the motion detection into electrical signals. Generally, there are three types of the motion sensor.

1. Passive infrared sensor (PIR)

It does not release energy or waves from the sensor. It's a sensor that receives heat from the body that is moving.

2. Ultrasonic

It's a sensor that releases ultrasonic wave and detects of the reflected wave when the object moves.

3. Microwave

It's a sensor that releases microwave and detects of the reflected wave when the object moves.

Passive infrared sensor (PIR)

Sensor is a device that detects movement by measuring the heat in the desired area. Infrared radiation is emitted more than usual when the life has a movement. Heat is measured by the level change of infrared radiation. The infrared radiation was delivered to the pyro electric, which convert heat from infrared radiation into electrical energy.

Features of the PIR sensor are as the following.

1. Be able to detect motion in the six meters.
2. The radius of detection is 70 degree.
3. The operating temperature range is 0 to 50 degrees Celsius (in the shade).
4. Take the time to learn the environment 10 to 60 seconds. During this time, there should be as little movement as possible in areas that have been detected.

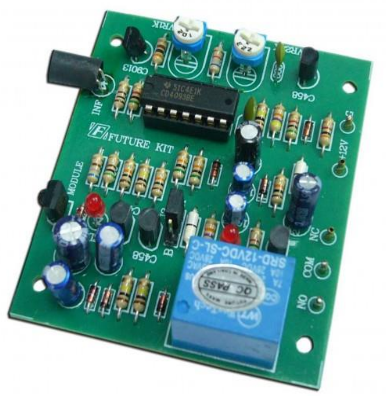


Figure 7 The internal circuit of passive infrared sensor

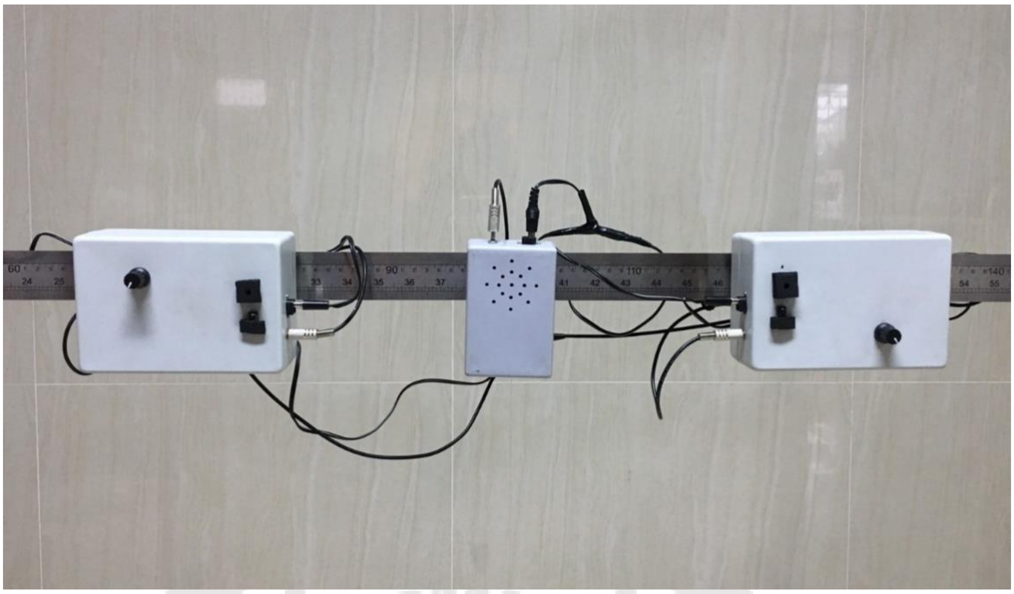


Figure 8 The two passive infrared sensors connected to speakers.

5. Balance assessment for stroke patient

Balance assessment tools can be classified into two major categories that are laboratory tools and clinical tools.

Laboratory tools are such as posturography, accelerometer, force plate, motion analysis system. Laboratory tools offer the information that cannot be seen with naked eyes. They provide objective and quantitative measurements that could be easily translated into a useful information for treatment.(Mancini & Horak, 2010) Furthermore, laboratory tools have a high reliability and validity, and without bias. However, some laboratory tools are complex equipments, and high cost. The physical therapist must have expertise in using the tools.

Clinical tools such as Berg Balance Scale (BBS), Timed Up and Go Test (TUG), Functional Reach Test (FRT), Balance Evaluation System Test (BESTest), Activities-specific Balance Confidence scale (ABC), Postural Assessment Scale for Stroke Patients (PASS), Community Balance and Mobility Scale (CB&M). Some tools are self-assessment such as ABC scale. The equipment used in the assessment for clinical tools is easy to find in the clinic. Also, it is easy to use, takes less time and widely use. The selection of the assessment tools should be suitable for the purpose and group evaluated. The chosen tools should also have high reliability and validity.

Berg Balance Scale

Berg Balance Scale (BBS) is the clinical scale that is the gold standard for measuring balance. The BBS was invented in 1989 by Berg and co-workers. The BBS has 14 functional items according to daily activities as sitting, sitting to standing, unsupported standing, standing to sitting, transfers from chair to chair, standing with eyes closed, standing with feet together, reaching forward with outstretched arm, retrieving object from floor, turning to look behind, turning 360 degrees, placing alternate foot on stool, standing with one foot in front, and standing on one foot. It takes only 15 minutes to complete the whole test. The equipments in the test include of stopwatch, chair, bed, ruler, and stool. Balance abilities of patients in each testing activity are assessed to be 0-4 points. The “0” score is unable to do the function and “4” score is able to complete the function based on the defined criteria. The total score is 56 points. The cut-off score risk of falling in stroke patient is 45 points. The reliability and validity of BBS was assessed in stroke patients. The inter-rater reliability of BBS was excellent (ICC = 0.95).(Mao, Hsueh, Tang, Sheu, & Hsieh, 2002) The test-retest reliability was excellent (ICC = 0.95).(Outermans, van Peppen, Wittink, Takken, & Kwakkel, 2010) Also, internal consistency (Cronbach's alphas = 0.92-0.98) and predictive and convergent validity (r = 0.82-0.91 and 0.89-0.94 respectively) were excellent.(Mao et al., 2002)

Functional Reach Test

Functional reach test (FRT) was developed to assess the standing stability in elderly, parkinson’s disease, spinal cord injury, stroke patients. Duncan PW and co-workers invented this assessment in 1990. The testing procedures are as follows. The tested subject is set to stand next to the wall that attached measuring tape, but not touching the wall. The position of an arm that closed to the wall is at 90 degrees shoulder flexion with elbow straight and fist closed. The assessor records the starting scaling number at the third metacarpal head on measuring tape. Then, let the tested subject reach as far forward as possible without taking a step or losing balance. The end position of the third metacarpal head was recorded by the assessor. Reach distance is the difference between the start and the end position. The patients will perform three times and the represented result will be the average.

FRT takes a short time and needs only measuring tape. So it is easy to use for clinical test. Meanwhile, it shows high reliability and validity. The reliability and validity of FRT assessed in patients with stroke were investigated. The intra-rater reliability of FRT was excellent (ICC = 0.89).(Outermans et al., 2010) And also, the face validity (r = 0.71) was excellent.(Outermans et al., 2010)

Timed up and go test

Timed up and go test (TUG) was developed for assessment of balance and mobility by Mathias and co-worker in 1986. . Start testing by the patient sitting in a chair with backrest and armrest. After the tester says "go", the patient will start standing up from a chair. Then, he/she will walk a distance of 3 meters, turn around, and walk back to the chair and sit down. Timing begins at the instruction "go" and stops when the patient is seated. Thespeed of walking is as quickly as the patients feel safe and comfortable. During walking, the patient may use or non-use gait aids and wear their own comfortable shoes. If they do not have appropriate shoes, they will walk with barefoot (no socks).

The reliability and validity of TUG was assessed in stroke patients. The test-retest reliability was excellent (ICC = 0.96 and 0.95).(Bagley et al., 2005; Flansbjer, Holmback, Downham, Patten, & Lexell, 2005) Also, convergent and discriminant validity (r = 0.86-0.99) were excellent.(Bagley et al., 2005; Flansbjer et al., 2005; Guyatt et al., 1985)

6. Weight bearing assessment

In clinical, the instruments for measuring weight-bearing include of digital bathroom scales and load monitors. (Movement analysis of individuals)

Digital bathroom scales

A digital bathroom scale is the simply applicable instrument for weight bearing assessment because it is low cost, small and easily to move. So, it is suitable for clinical use according to the previous studies in patients with stroke about the maximum weight-bearing of affected side. Dettman and co-worker in 1987 demonstrated about the maximum weight-bearing of affected side in fifteen stroke patients by using bathroom scales to assess. They found that the maximum weight-bearing of the affected side had high correlation with functional assessment.(Dettmann, Linder, & Sepic, 1987) Moreover, Bohannon and co-worker in 1991 found that the maximum weight-bearing of affected side had high correlation with gait speed (r=0.830).(Bohannon, 1991)

The weight-bearing measure used two digital bathroom scales that were placed on flat surface. The patients with stroke stood on two digital bathroom scales placed side-by-side. They were asked to standing comfortably with each foot was placed on each bathroom scale, and two arms crossed on a chest and then looking straight ahead, and shifting weight onto affected side as much as possible. Physical therapist record the weight displayed. Repeat the test three times. The maximum value of the weight bearing on the affected foot was a representative data for analysis.(Marie Cameron, 1999)

The calibration of the digital bathroom scales was done by standard pendulums. Maximum weight of digital bathroom scale was divided into 10 equal intervals. For example, the maximum weight was 150 kilograms. It was divided into 15, 30, 45, 60, 75, 90, 105, 120, 135, and 150 kilograms. Each weight was tested four times. An average value was calculated for correction value. The correction value was "the discrepancy value between the scales and weight of the standard pendulum.(จารุวาระกูล, 2548)

From $C_s = \bar{x} - N$

When, C_s is the correction value.

$\bar{x}$ is the average value of weighting four times.

N is weight of the standard pendulum.

So, Valid value = scale value + correction value

Repeatability is another important test. This can be done by calculating the standard deviation (S.D.) from weighting repeat 10 times. Weight 10% and 90% of maximum weight were weighted repeat.(จารุวาระกูล, 2548) S.D. should not exceed the uncertainty of a given manufacturer.(ฝ่ายห้องปฏิบัติการสถาบันบริการตรวจสอบคุณภาพและมาตรฐานผลิตภัณฑ์, 2555)

$$S.D. = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$$

CHAPTER 3
METHODOLOGY

1. Research design

This study is a randomized controlled trial with two arms that included of experimental and control groups. The physical therapist who performed the balance assessments was blinded to the treatment allocations.

2. Subjects

Twenty four patients aged 45 to 65 years with a first-ever ischemic or hemorrhagic stroke shown by computerized tomography or magnetic resonance imaging within 1 to 6 months prior to enroll the study were recruited.

The inclusion criteria of subjects were as follows:

1. Able to stand independently on a stable surface without an assistive device for 30 seconds
2. Able to walk on floor at least 6 meters without assistant, may be with or without gait aids
3. Weight bearing on the affected side during quiet stance less than 40% of body weight
4. Spasticity of the affected lower limb less than or equal to grade 2 as classified by Modified ashworth scale
5. Stable vital signs or medical status
6. Without peripheral neuritis and musculoskeletal problems such as low back pain or arthritis that affect motor performance
7. Mini – Mental State Examination: Thai version (MMSE – Thai 2002) score is equal to or more than 23 points.

The patients were excluded if they showed any of the following conditions:

1. Having other neurological conditions beside stroke
2. Aphasia
3. Neglect syndrome

4. Amputation of the lower limb

5. Hearing problems even with hearing aids

All the patients were informed about aims, protocol, and benefits of the study before they decided to participate and signed a written informed consent. The study was approved by the ethics committee of the Faculty of Physical therapy, Srinakharinwirot University. The code of a research ethical approval is PTPT 2017-003.

3. Sample size calculation

According to the previous study "Effect of rhythmic auditory stimulation on gait and balance in hemiplegic stroke patients" by Jee Hyun Suh and co-workers in 2014, they measured stride length, gait velocity, cadence and standing balance. These outcomes were assessed by using Biosway® (Biodex, NewYork, USA). After the training, they found that a mean and standard deviation of standing balance in experimental group was 0.79 ± 0.54 degrees and the control group was 1.38 ± 0.30 degrees[50]. The G power program was used to calculate the sample size with setting the power = 0.8, α = 0.05 and using the mean and standard deviation of the previous study to determine an effect size d. The calculated total sample size was 20 persons, then added 20% for drop out. Therefore, the appropriate total sample size including the adjusted drop out was 24 persons (12 persons for an experimental group and the other 12 persons for a control group).

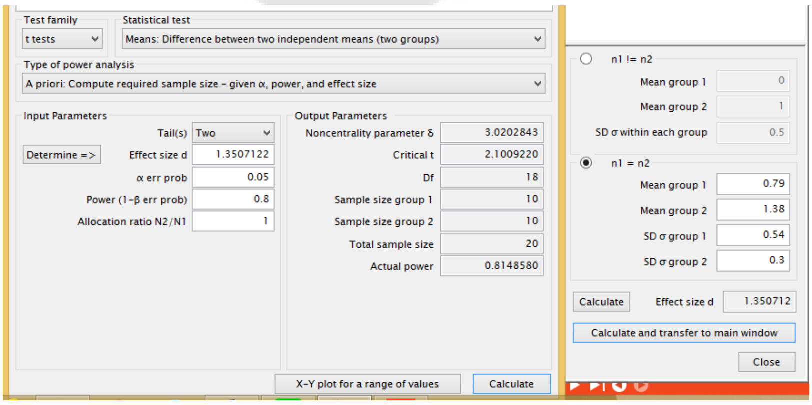


Figure 9 The sample size calculation by using G* power program 3.1.9.2

4.Outcome measures

All patients were assessed their balance ability using the Berg balance scale, functional reach test, timed up and go test, and a percentage of weight bearing on the affected leg before and after four weeks of training. The weight bearing on the affected foot was assessed by the digital bathroom scale. The physical therapist performing the balance assessments was blinded to the treatment allocations. The posttest was conducted a day after the end of the intervention period.

Berg balance scale (BBS) was used to assess for indicating ability of balance during doing tasks. The BBS tests balance performance in 14 activities that are unsupported sitting, sitting to standing, unsupported standing, standing to sitting, transfers from chair to chair, standing with eyes closed, standing with feet together, reaching forward with outstretched arm, retrieving object from floor, turning to look behind, turning 360 degrees, placing alternate foot on stool, standing with one foot in front, and standing on one foot. There are five level of scores for each activity, from 0-4 points. The "0" indicates the lowest level and "4" indicates the highest level. During BBS assessing, if the patient is tired, they can sit and rest until they are recovered.

Functional reach test (FRT) was used to evaluate standing stability limit in each directions. The patients were asked to standing with the unaffected side next to the wall on which a measuring tape attached, but not touching or leaning on the wall. The position of the unaffected arm that closed to the wall is at 90 degrees of shoulder flexion with elbow straight and fist closed. Physical therapist (assessor) recorded a starting position by the scaling number on the measuring tape at the third metacarpal head. Then, the assessor instructed the patient to reach forward as far as possible without taking a step or losing balance. The end position of reaching at the third metacarpal head will be recorded by the assessor. Reach distance is the length between the starting and the ending position. The patients performed three times of functional reach and the represented reaching distance were the average.

Timed up and go test (TUG) was used to assess balance in gait. The test was started by the patient sitting in a chair with backrest and armrest. After the physical therapist said “go”, the patients stood up from a chair. Then, they walked a distance of 3 meters, turned around, and walked back to the chair and sat down. Timing began at the instruction “go” and stopped when the patient was seated. The speed of walking was as fast as the patients feeling safe and comfortable. During walking, the patient may use or non-use gait aids and wear their own comfortable shoes. If they do not have appropriate shoes, they will walk with barefoot (no socks).

The two digital bathroom scales were used to assess weight bearing on both feet during comfortable stance before and after training. The stroke patients were asked to stand on two scales which placed side-by-side with each foot on each scale and arms crossed at their chest and looked straight ahead. Then, they were asked to shift weight onto the affected foot as much as possible. The weight on a digital scale under the affected foot was recorded. The test was repeated 2 times and recorded the highest value. Time to break between each time was ten seconds.

5. Materials and research tools

The materials used in this study included of the followings.

1. Mini – Mental State Examination: Thai version (MMSE – Thai 2002) score
2. Berg Balance Scale
3. Functional reach test
4. Timed up and go test
5. Two digital bathroom scales
6. Measuring tape
7. Chair with arm rests and back rest
8. Color tape or cone
9. The developed balance training device with auditory feedback by PIR sensor
10. Belt

6. Intervention

Group design

Twenty four patients with stroke who volunteered and fit to the inclusion criteria were randomly assigned to either the experimental group (n = 12) or the control group (n = 12). The patients in the experimental group enrolled in a session composed of a conventional rehabilitation program including stretching and strengthening exercise for 30 minutes and balance training using the developed balance training device with auditory feedback by passive infrared sensor for 30 minutes, 5 sessions a week for 4 weeks while those in the control group received only a conventional rehabilitation program for 1 hour/session, 5 sessions a week for 4 weeks. The conventional rehabilitation program for all patients in this study were provided by the rehabilitation center physical therapist. The program was patient-specific including stretching and strengthening exercise for 30 minutes and balance training without using the balance training device for 30 minutes.

Balance training with a developed auditory feedback balance training device using PIR sensor

Each patient was asked to start from standing with feet apart at pelvis width and facing to the center of the device but away from it 0.5 meters as shown in figure 10a and 10c. Their arms were placed in a comfortably over their chest and look straight ahead. All patients had to wear their own shoes with or without AFO during training. The height of the sensor was adjusted at the same level as the L3-L4 of each patient as figure 10. Then, the physical therapist gradually set the distance of the sensor away from the center of the device to challenge the patients to practice weight-shift on the affected side until reach into a detectable range of the passive infrared sensor that results in producing a feedback sound signal and urged them trying to maintain posture at that point for 10 seconds. To train the weight shift, the PIR sensor was set at 1 centimeter beyond a distance that patients can take the weight to. Each patient was belted for safety. For progression of training, the physical therapist had to move the sensor setting beyond the original point and facilitated the patient to shift weight farther to the new setting distance. The new distance setting of the sensor was gradually increased but no more than normal limit of stability. Murray and co-worker in 1975 studied about maximum distance of COP displacement in different age groups. They found that the age group 40-50 years had the maximum COP displacement in forward, backward, and lateral directions were 7.5±0.9, 4.4±1.1, and 6.4±1.2 cm. ($p<0.05$) respectively. The age group 60-70 years had the maximum COP displacement in forward, backward, and lateral directions were 8.0±1.3, 6.2±2.4, and 7.3±1.6 cm. ($p<0.05$) respectively. The weight shifting activities will be train in four directions; left, right, front and back.

When, patients were able to do weight shift between both feet. The next step, the physical therapist was gradually set the distance of the sensor more away from the center of the device 5-10 centimeters to challenge the patients for stepping practice to the affected side until the passive infrared sensor had a voice and urged them trying to maintain posture at that point for 10 seconds. Repeat 10 times for each distance and direction. During the training, if the patient is tired, let he/she sit and rest until recover.

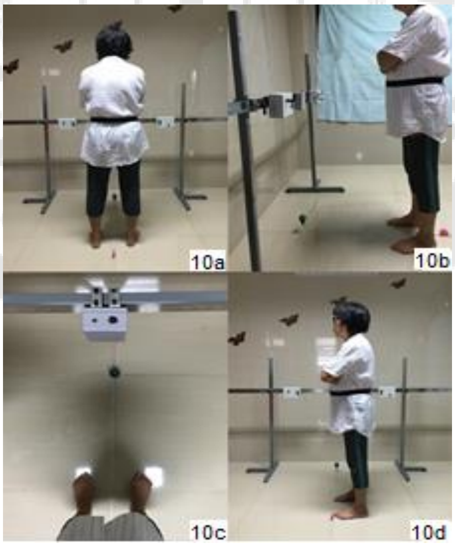


Figure 10 a) The infrared sensors are set parallel at the same level of L3-L4 from posterior view, b) The starting position for weight shift training in left-right directions by standing facing to the sensors, c) The distance that patient standing away from the device 0.5 meters from above view, and d) The starting position for weight shift training in front and back directions by standing with lateral side opposed to the sensors.

7. Data analysis

The processes of statistical analysis were as follows. Firstly, Kolmogorov-Smirnov Test was used to test the data distribution of the studied parameters. Then, comparison of the studied parameters between before and after training in each group was analyzed by Paired sample T-test. The Independent sample T-test was used to compare the changed values of the studied variables between experimental and control groups because the data was normal distribution, except the changed values of TUG outcome were compared between the two groups by the Mann-Whitney U test because the data was not normal distribution. Statistical significance level for analysis was set at P value <0.05.

8. Ethical considerations

This research was approved by the ethical committee of the Faculty of Physical Therapy, Srinakharinwirot University. The ethic approval code is PTPT 2017-003.

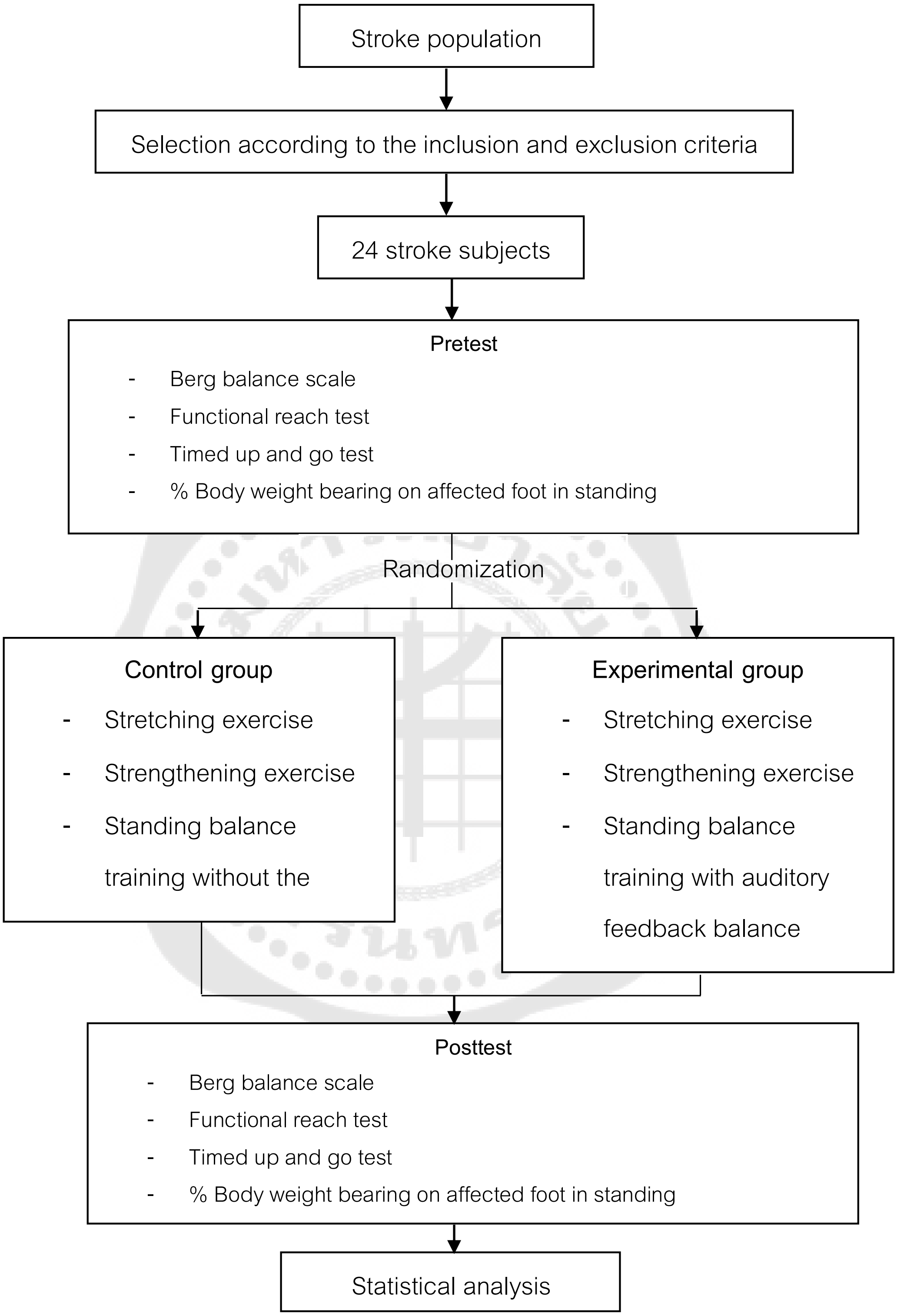


Figure 11 Flow chart of procedure

CHAPTER 4
RESULTS

This study investigated the effects of balance training by using the developed balance training device with an auditory feedback from passive infrared (PIR) sensors. The studied outcomes to prove the effects included of berg balance scale, functional reach test, timed up and go test and a percentage of body weight bearing on the affected foot in standing (%BW). The patients in the experimental group received a conventional rehabilitation program of stretching and strengthening exercise for 30 minutes and a balance training by the developed balance training device with an auditory feedback by passive infrared sensor for 30 minutes, 5 sessions a week for 4 weeks while the patients in a control group received only the conventional rehabilitation program of stretching and strengthening exercise for 30 minutes and a balance training without using the device for 30 minutes, 5 sessions a week for 4 weeks.

Participants

Twenty-four stroke patients participated in this study. The patients were randomly assigned to be a control (n = 12), and an experimental (n = 12) groups. Mean age of the control group was 59.0 ± 4.43 years, and that of the experimental group was 59.25 ± 5.43 years. The other general characteristics of the subjects are shown in Table 1. The baseline charateristics related to age, time from stroke prior to enrollment, Brunnstrom stage, MMSE scores and MAS scores of the participants in the experimental and control groups were not significantly different, except %BW. At baseline, the experimental group demonstrated higher %BW on the affected foot in standing than the control group significantly (p=0.027). Therefore, to reduce the bias, this study used the changed values of the studied outcomes from the baseline for comparison of the treatment effect between experimental and control groups.

Table 1 Characteristics of participants with stroke in the control and experimental groups at baseline

Characteristics	Control group (n = 12)	Experimental group (n = 12)	p value#
Age (years)	59.0±4.43	59.25±5.43	0.90
Gender			
Male	8	7	
Female	4	5	
The affected side			
Left	8	9	
Right	4	3	
Type of stroke			
Ischemic	7	9	
Hemorrhagic	5	3	
Time from stroke prior to enrollment (months)	2.92±1.1	3.0±1.21	0.86
Brunnstrom stage	2.25±0.75	1.92±0.79	0.30
MMSE-Thai (scores)	29.25±1.49	28.17±2.89	0.26
MAS (scores)	0.88±0.71	0.96±0.66	0.97
Percentage of body weight bearing on the affected foot in standing (%BW)	23.07±8.62	30.16±5.81	0.027*

Note: # p-value of the comparison between control and experimental groups by independent t-test

* significant difference between control and experimental groups at $p < 0.05$

Abbreviations: MMSE-Thai= Mini – Mental State Examination: Thai version (MMSE – Thai 2002), MAS= Modified Ashworth Scale

Comparison of the studied parameters within group

After training, the percentage of body weight bearing on the affected foot in standing (%BW), Functional Reach Test (FRT), Berg Balance Scale (BBS) and Timed Up and Go test (TUG) were significantly increased when compared to the baseline for the experimental group (p<0.05) as shown in Table 2. Although, no statistically significant change was found in all studied parameters after training for the control group, there was a tendency of BBS improvement that was nearly statistical significance (p=0.054) as shown in Table 2.

Table 2 Comparison of FRT, BBS, TUG and a percentage of weight bearing on the affected foot between pre-test and post-test within a control group and an experimental group.

Studied parameters	Control group (n = 12)			Experimental group (n = 12)		
	Pre-test	Post-test	p-value	Pre-test	Post-test	p-value
Percentage of body weight bearing on the affected foot in standing (%BW)	23.07±8.62	25.24±9.06	0.415	30.16±5.81	42.85±7.12	0.001**
FRT(cm.)	20.34±7.32	20.23±8.61	0.977	20.34±6.38	25.14±6.77	0.001**
BBS(scores)	32.25±11.21	35.42±8.98	0.054	36.75±8.63	44.83±5.24	0.001**
TUG (seconds)	65.27±35.17	64.02±36.09	0.429	60.03±33.44	35.99±15.71	0.012*

Note: Data are presented as mean ± SD., ** significant difference between pre- and post-test at p < 0.01 by Paired sample t-test, * significant difference between pre- and post-test at p < 0.05 by Paired sample t-test

Abbreviations: FRT=Functional Reach Test, BBS=Berg Balance Scale, TUG=Timed Up and Go test

Comparison of the studied parameters between control and experimental groups

The changed values of the studied parameters from the baseline after training of the control and experimental groups were shown in Table 3. The experimental group had significantly higher improvements in the %BW, BBS scores and TUG when compared to the control group, except FRT.

Table 3 Comparison of the changed values from baseline of the studied parameters after training between control and experimental groups.

Studied parameters	Changed value from baseline		p-value
	control group	experimental group	
Percentage of body weight bearing on the affected foot in standing (%BW)	2.17±2.56	13.73±1.49	0.001**
FRT (cm.)	0.72±2.51	4.80±0.97	0.053
BBS (scores)	3.17±1.47	8.17±1.42	0.023*
TUG (seconds)	1.25±1.52	20.74±8.8	0.038#

Note: Data is presented as mean ± SE., # significant difference between control and experimental groups at $p < 0.05$ by Mann-Whitney U test , ** significant difference between control and experimental groups at $p < 0.01$ by independent t-test,

* significant difference between control and experimental groups at $p < 0.05$ by independent t-test

.Abbreviations: FRT=Functional Reach Test, BBS=Berg Balance Scale, TUG=Timed Up and Go test

CHAPTER 5
DISCUSSION

This study was conducted to investigate the effect of balance training by using the developed balance training device with an auditory feedback from passive infrared (PIR) sensors. After training, the experimental group that was trained by the developed device showed significant improvements of percentage of body weight bearing on the affected foot in standing (%BW), Berg Balance Scale (BBS), Functional reach test (FRT), and Timed Up and Go test (TUG). And the experimental group also significantly showed better improvements of those studied outcomes than the control group, except FRT.

The principle of training by the developed device of this study is to facilitate the patients' relearning how to do weight shifting to the affected leg in various directions and to challenge them for the progression by increasing the COM displacement with guidance by an auditory feedback from PIR sensor. The auditory feedback from the PIR sensor acts as an augmented extrinsic feedback that provides information for encouraging a motor learning during weight shifting activity. The auditory feedback can help the patients know the result of their performance and relearn to adjust the CoM displacement to a proper target during weight shifting practice.(de Haart et al., 2005; Li, Han, Sheng, & Ma, 2016) So, the auditory feedback from PIR sensor of the develop device can motivate motor relearning how to control of CoM displacement in weight shifting activity for the stroke patient.

The training protocol of this study encourages weight shifting to various directions. One of the directions is accounting for the affected leg. So, the subjects can relearn how to control the CoM displacement to the affected leg during weight shifting practice. Moreover, the weight shifting training may also promote other essential components of postural control, for example; cognitive processing, perception of verticality, movement strategies, and sensory integration.(de Haart et al., 2005; Jung et al., 2014; Tsaklis et al., 2012) In addition, weight bearing on the affected leg may also benefit in reducing biomechanical constraint affecting balance in standing, such as hypertonia and tightness of plantar flexor which commonly found in stroke.

The significant improvement of BBS and TUG of the stroke patients in the experimental group may due to the more evenness of weight bearing and the better weight shifting performance onto the affected leg. This can be supported by the significant increase in a percentage of body weight bearing on the affected foot that found in the experimental group at post-training which was more than the baseline and more than that of the control group. According to the previous studies in stroke patients, the better functional ability and faster gait velocity of the patients were correlated with the better weight bearing on the affected foot.(Cheng et al., 2001; de Haart et al., 2005; Jung et al., 2014; Tsaklis et al., 2012)

The better weight shifting performance to the affected leg of the patients after training can improve BBS scores because almost of the test items in BBS relies mainly on the ability in weight shifting between two legs such as transfer activity, reaching forward with outstretched arm while standing, turning to look behind in standing, turning 360 degrees, alternate foot placing on a step while standing and standing on one leg. Similarly, all activities in TUG including sit-to-stand, walking, turning and stand-to-sit, also need a good control of CoM displacement and weight shifting between two legs. Therefore, the better weight shifting performance to the affected leg of the patients after training can help them walk faster in TUG test as well.

In addition, after training, the changed values from the baseline of BBS and TUG that found in the experimental group are larger than the minimal detectable change (MDC) that were cited in the studies of Flansbjer and Blom in 2012(Flansbjer, Blom, & Brogardh, 2012), and Flansbjer and Holmback in 2005 respectively.(Flansbjer et al., 2005) These can confirm that the training protocol by using the developed device with an auditory feedback from PIR sensor of this study is really clinically effective for promoting a symmetrical weight bearing on both legs and the functional balance in persons with subacute stroke. Furthermore, according to the BBS predicting falls risk from the study of Doggan et al in 2011(Dogan, Mengulluoglu, & Ozgirgin, 2011), the stroke patients in the experimental group of this study increased BBS score from 36.75±8.63 to 44.83±5.24 after training and reached to a less falls risk when compared with baseline. Therefore, a balance training protocol by using the developed balance training device with an auditory feedback from passive infrared (PIR) sensors of this study can improve balance performance and reduce falls risk of the stroke patients.

However, this study found that the improvement of FRT in the experimental group did not differ from that of the control group. This may because, at baseline, both groups were able to reach forward within the average range of reaching distance or within the stability limit as normal elderly.(Bohannon, Wolfson, & White, 2017) Therefore, the improved FRT distance may not be large enough to make it differ from the control group.

The improvement of balance outcomes in the experimental group after training by using the developed balance training device with an auditory feedback from passive infrared (PIR) sensors in this study are according to previous studies related to t balance training in people with stroke by using other devices.(Bagley et al., 2005; Bower et al., 2014; Cho et al., 2012; Ding et al., 2013; Goljar et al., 2010; Gonzalez-Fernandez et al., 2010; Lee et al., 1996; Song et al., 2014) The duration of training (4 weeks) is also accordance with the previous studies. Therefore, with the effectiveness of balance training outcomes by the developed PIR device and its available price of 2500 baht, the developed PIR device sound to be an interesting device applying for balance training in subacute stroke. However, from the inclusion and exclusion criteria of the subjects, the protocol of balance training by using the developed PIR device of this study is appropriate for stroke patient in sub-acute phase with specific conditions atleast be able to stand independently without assistive device for at least 30 seconds and without problems of cognitive function, aphasia, neglect, or hearing. Thus, the conventional rehabilitation program is still a basic need for the early stage of the stroke patients before using a balance training protocol with the developed PIR device.

Meanwhile, the control group, which received a conventional rehabilitation program, did not demonstrated statistical significant improvements of %BW on the affected leg, BBS, FRT, and TUG after 4 weeks of training when compared to baseline. These may due to most of subjects in the control group had %BW bearing on the affected leg at baseline poorer than the experimental group significantly although the researcher did the group randomization. Therefore, the patient in the control group may need a longer time (more than 4 weeks) for training to improve their weight shifting ability onto the affected leg.

There are many factors that affect the stroke recovery such as age, gender, nationality, socio-economic status, type of stroke, time from stroke, motor recovery, complications, cognitive status, depression and rehabilitation programs.(Alawieh, Zhao, & Feng, 2018; Dusica, Devecerski, Jovicevic, & Platisa, 2015) From statistical analysis of the baseline characteristics of participants in this study, age, time from stroke, Brunnstrom stage, MMSE scores and MAS scores in the experimental and control groups were not significantly different. Nevertheless, the types of stroke in the experimental group and in the control group were different. The experimental group had nine ischemic and three hemorrhagic strokes, while the control group had seven ischemic and five hemorrhagic strokes. The more hemorrhagic strokes in the control group than the experimental group may be one factor effecting on less outcomes' improvement of the control group because, from previous study, the hemorrhagic stroke showed prevalence of more severity, poor prognosis and mortality than ischemic stroke.(Andersen, Olsen, Dehlendorff, & Kammersgaard, 2009) In addition, the participants in experimental group had the better motor recovery (Brunnstrom stage 3) than the control group. Therefore, the control group may tend to have a slower motor recovery than the experimental group. However, the control group still showed a tendency of slightly increases in %BW bearing on the affected leg and BBS score after conventional rehabilitation training.

The limitation of this study is that the balance training by using the developed device with auditory feedback from PIR sensors of this study was performed in a silent room. Therefore, it cannot extend the results of the training by the developed device in the community where there are several distractive noises. This study did not follow-up the outcomes beyond the 4th week of training. Therefore, the sustained effect of the training was not declared by this study. Additionally, there was one patient's complaint about boringness and dizziness because thirty minutes was a long period of practice.

Therefore, the protocol for balance training by using the developed device with auditory feedback from PIR sensors should be adjusted to be a shorter interval practice instead of a thirty-minute period to solve the boringness and dizziness complaints and should also investigate further for the interval practice effects. Furthermore, the benefits of balance training by using the developed device with auditory feedback from PIR sensors in individuals with balance impairment caused by other pathologies, such as Parkinsonism and spinal cord injury, are also interesting for the future studies.

CHAPTER 6
CONCLUSION

The balance training program by using the developed balance training device with an auditory feedback from passive infrared (PIR) sensors combined with the conventional rehabilitation program can improve balance performance during quiet standing, forward reaching and walking in sub-acute stroke patients better than the only conventional rehabilitation.

The principle of training by the developed device is to facilitate the patient relearning how to do weight shifting to the affected leg in various directions by the auditory feedback from PIR sensor and also challenge them for the progression to displace their COM farther by gradually moving the sensor away from the patients. Therefore, the developed balance training device with an auditory feedback from PIR sensor of this study can apply for weight shifting practice to improve balance performance of the people with stroke in sub-acute phase.

APPENDICES

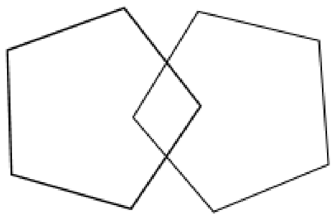
Appendix A

Mini – Mental State Examination: Thai version (MMSE – Thai 2002)

ชื่อ-นามสกุล...วันที่...................................

คำถามหรือคำสั่ง	คำตอบ	คะแนนที่ได้
1. Orientation for time (5 คะแนน) (ตอบถูกข้อละ 1 คะแนน) 1.1 วันนี้วันที่เท่าไร 1.2 วันนี้วันอะไร 1.3 เดือนนี้เดือนอะไร 1.4 ปีนี้ปีอะไร 1.5 ฤดูนี้ฤดูอะไร		
2. Orientation for place (5 คะแนน) (ให้เลือกข้อใดข้อหนึ่ง) (ตอบถูกข้อละ 1 คะแนน) 2.1 กรณีอยู่ที่สถานพยาบาล 2.1.1 สถานที่ตรงนี้เรียกว่า อะไรและ......ชื่อว่าอะไร 2.1.2 ขณะนี้ท่านอยู่ที่ชั้นที่เท่าไรของตัวอาคาร 2.1.3 ที่นี่อยู่ในอำเภอ/เขตอะไร 2.1.4 ที่นี่จังหวัดอะไร 2.1.5 ที่นี่ภาคอะไร 2.2 กรณีที่อยู่ที่บ้านของผู้ถูกทดสอบ 2.2.1 สถานที่ตรงนี้เรียกว่าอะไรและบ้านเลขที่เท่าไร 2.2.2 ที่นี่หมู่บ้าน หรือละแวก/คุ้ม/ย่าน/ถนนอะไร 2.2.3 ที่นี่อยู่ในอำเภอ/เขตอะไร 2.2.4 ที่นี่จังหวัดอะไร 2.2.5 ที่นี่ภาคอะไร		
3. Registration (3 คะแนน) บอกชื่อของ 3 อย่างเพียงครั้งเดียวเมื่อพูดจบให้ผู้ถูกทดสอบพูดทบทวนตามที่ได้ยิน ให้ครบทั้ง 3 อย่าง (ตอบถูก 1 คำได้ 1 คะแนน) ○ดอกไม้ ○แม่น้ำ ○รถไฟ ในกรณีที่ทำแบบทดสอบซ้ำภายใน 2 เดือน ให้ใช้คำว่า ○ต้นไม้ ○ทะเล ○รถยนต์		

4. Attention/Calculation (5 คะแนน) (ให้เลือกข้อใดข้อหนึ่ง)ถ้าผู้ถูกทดสอบคิดเลขในใจเป็นให้ทำข้อ 4.1 ถ้าคิดไม่เป็นให้ทำข้อ 4.2 4.1 คิดเลขในใจให้เอา 100 ตั้งลบออกทีละ 7 ไปเรื่อยๆได้ผลลัพธ์เท่าไรทำทั้งหมด 5 ครั้ง (ถ้าลบได้ 1, 2, หรือ 3 แล้วตอบไม่ได้ ก็คิดคะแนนเท่าที่ทำได้ ไม่ต้องย้ายไปทำข้อ 4.2) 4.2 สะกดคำว่ามะนาวให้ฟัง"มอม้า-สระอะ-นอหนู-สระอา-วอแหวน" แล้วให้ผู้ถูกทดสอบสะกดถอยหลังจากพยัญชนะตัวหลังไปตัวแรก .... วานะม		
5. Recall (3 คะแนน) เมื่อสักครู่ที่ให้จำของ 3 อย่าง จำได้ไหมมีอะไรบ้าง" (ตอบถูก 1 คำได้ 1 คะแนน) ○ ดอกไม้ ○ แม่น้ำ ○ รถไฟ ในกรณีที่ทำแบบทดสอบซ้ำภายใน 2 เดือน ให้ใช้คำว่า ○ ต้นไม้○ ทะเล ○รถยนต์		
6. Naming (2 คะแนน) 6.1 ยื่นดินสอให้ผู้ถูกทดสอบดูแล้วถามว่า "ของสิ่งนี้เรียกว่าอะไร" 6.2 ชี้นาฬิกาข้อมือให้ผู้ถูกทดสอบดูแล้วถามว่า "ของสิ่งนี้เรียกว่าอะไร"		
7. Repetition (1 คะแนน) (พูดตามได้ถูกต้องได้ 1 คะแนน) พูดข้อความนี้แล้วให้ผู้ถูกทดสอบพูดตาม โดยบอกเพียงครั้งเดียว "ใครใคร่ขายไก่ไข่"		
8. Verbal command (3 คะแนน) บอกผู้ถูกทดสอบว่าจะส่งกระดาษให้ แล้วให้รับด้วยมือขวาพับครึ่งด้วยมือ 2 ข้างแล้ววางไว้ที่..................... (พื้น/โต๊ะ/เตียง) ผู้ทดสอบส่งกระดาษเปล่าขนาดประมาณเอ-4 ไม่มีรอยพับให้ผู้ถูกทดสอบ ○ รับด้วยมือขวา ○ พับครึ่ง ○ วางไว้ที่ (พื้น/โต๊ะ/เตียง)		
9. Written command (1 คะแนน) ให้ผู้ถูกทดสอบอ่านข้อความที่กำหนดแล้วให้ทำตามจะอ่านออกเสียงหรืออ่านในใจก็ได้ผู้ทดสอบแสดงกระดาษที่เขียนว่า "หลับตา" ○ หลับตาได้		

10. Writing (1 คะแนน) ให้ผู้ถูกทดสอบเขียนข้อความอะไรก็ได้ที่อ่านแล้วรู้เรื่อง หรือมีความหมายมา 1 ประโยค O ประโยคมีความหมาย		
11. Visuo construction (1 คะแนน) ข้อนี้เป็นคำสั่ง "จงวาดภาพให้เหมือนภาพตัวอย่าง" 		

Appendix B

Berg Balance Scale

Name...Date....................................

Items	Instructions	Scores
1. Sitting to standing	Please stand up. Try not to use your hands for support.	4) = able to stand without using hands and stabilize independently 3) = able to stand independently using hands 2) = able to stand using hands after several tries 1) = needs minimal aid to stand or stabilize 0) = needs moderate or maximal assist to stand
2. Standing unsupported	Please stand for two minutes without holding on.	4) = able to stand safely for 2 minutes 3) = able to stand 2 minutes with supervision 2) = able to stand 30 seconds unsupported 1) = needs several tries to stand 30 seconds unsupported 0) = unable to stand 30 seconds unsupported
3. Sitting with back unsupported but feet supported on floor or on stool	Please sit with arms folded for 2 minutes.	4) = able to sit safely and securely for 2 minutes 3) = able to sit 2 minutes under supervision 2) = able to able to sit 30 seconds 1) = able to sit 10 seconds 0) = unable to sit without support 10 seconds
4. Standing to sitting	Please sit down.	4) = sits safely with minimal use of hands 3) = controls descent by using hands

Items	Instructions	Scores
		2) = uses back of legs against chair to control descent 1) = sits independently but has uncontrolled descent 0) = needs assist to sit
5. Transfers	Arrange chair(s) for pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.	4) = able to transfer safely with minor use of hands 3) = able to transfer safely definite need of hands 2) = able to transfer with verbal cuing and/or supervision 1) = needs one person to assist 0) = needs two people to assist or supervise to be safe
6. Standing unsupported with eyes closed	Please close your eyes and stand still for 10 seconds.	4) = able to stand 10 seconds safely 3) = able to stand 10 seconds with supervision 2) = able to stand 3 seconds 1) = unable to keep eyes closed 3 seconds but stays safely 0) = needs help to keep from falling
7. Standing unsupported with feet together	Place your feet together and stand without holding on.	4) = able to place feet together independently and stand 1 minute safely 3) = able to place feet together independently and stand 1 minute with supervision

Items	Instructions	Scores
		2) = able to place feet together independently but unable to hold for 30 seconds 1) = needs help to attain position but able to stand 15 seconds feet together 0) = needs help to attain position and unable to hold for 15 seconds
8. Reaching forward with outstretched arm while standing	Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at the end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.)	4) = can reach forward confidently 25 cm (10 inches) 3) = can reach forward 12 cm (5 inches) 2) = can reach forward 5 cm (2 inches) 1) = reaches forward but needs supervision 0) = loses balance while trying/requires external support
9. Pick up object from the floor from a standing position	Pick up the shoe/slipper, which is place in front of your feet.	4) = able to pick up slipper safely and easily 3) = able to pick up slipper but needs supervision 2) = unable to pick up but reaches 2-5 cm(1-2 inches) from slipper and keeps balance independently

Items	Instructions	Scores
		1) = unable to pick up and needs supervision while trying 0) = unable to try/needs assist to keep from losing balance or falling
10. Turning to look behind over left and right shoulders while standing	Turn to look directly behind you over toward the left shoulder. Repeat to the right. Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.	4) = looks behind from both sides and weight shifts well 3) = looks behind one side only other side shows less weight shift 2) = turns sideways only but maintains balance 1) = needs supervision when turning 0) = needs assist to keep from losing balance or falling
11. Turn 360 degrees	Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.	4) = able to turn 360 degrees safely in 4 seconds or less 3) = able to turn 360 degrees safely one side only 4 seconds or less 2) = able to turn 360 degrees safely but slowly 1) = needs close supervision or verbal cuing 0) = needs assistance while turning
12. Place alternate foot on step or stool while standing unsupported	Place each foot alternately on the step/stool. Continue until each foot has touch the step/stool four times.	4) = able to stand independently and safely and complete 8 steps in 20 seconds 3) = able to stand independently and complete 8 steps in > 20 seconds 2) = able to complete 4 steps without aid with supervision 1) = able to complete > 2 steps needs minimal assist

Items	Instructions	Scores
		0) = needs assistance to keep from falling/unable to try
13. Standing unsupported one foot in front	Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride width.)	4) = able to place foot tandem independently and hold 30 seconds 3) = able to place foot ahead independently and hold 30 seconds 2) = able to take small step independently and hold 30 seconds 1) = needs help to step but can hold 15 seconds 0) = loses balance while stepping or standing
14. Standing on one leg	Stand on one leg as long as you can without holding on.	4) = able to lift leg independently and hold > 10 seconds 3) = able to lift leg independently and hold 5-10 seconds 2) = able to lift leg independently and hold ≥ 3 seconds 1) = tries to lift leg unable to hold 3 seconds but remains standing independently. 0) = unable to try of needs assist to prevent fall

Appendix C

Assessment Form (pre/post-training)

Name...Age........................ Sex................

Diagnosis.. Onset...................................

Weight.................... Height.................. BP........................ HR..................... Temp. ....

Assessment date......................................

	Score	Note
MMSE score		
Modified Ashworth scale		
Brunnstrom stage		
Berg balance scale	1.Sitting to standing	
	2.Standing unsupported	
	3.Sitting with back unsupported but feet supported on floor or on stool	
	4.Standing to sitting	
	5.Transfers	
	6.Standing unsupported with eyes closed	
	7.Standing unsupported with feet together	
	8.Reaching forward with outstretched arm while standing .... cm.	
	9.Pick up object from the floor from a standing position	
	10.Turning to look behind over left and right shoulders while standing	
	11.Turn 360 degrees	
	12.Place alternate foot on step or stool while standing unsupported	
	13.Standing unsupported one foot in front	
	14.Standing on one leg	
	Total	
Functional reach test	1)....................... cm. 2).......................cm. 3)....................... cm.	
% weight on affected side	1) 2) 3)	
Timed up and go test	1) 2) 3)	

Appendix D

Validity test of the bathroom scales for weight bearing assessment

Table D1 Raw data of the weight of standard pendulums and the weight measured by each digital bathroom screen

weight of standard pendulums	1st digital bathroom screen				2nd digital bathroom screen			
	Time 1	Time 2	Time 3	Average	Time 1	Time 2	Time 3	Average
5	5.0	5.0	5.0	5.00	5.0	5.0	5.0	5.00
10	10.0	10.0	10.0	10.00	10.0	10.0	10.0	10.00
15	15.0	15.0	15.0	15.00	15.0	15.0	15.0	15.00
20	20.0	20.0	20.0	20.00	20.0	20.0	20.0	20.00
25	25.0	25.0	25.1	25.03	25.0	25.0	25.0	25.00
30	30.0	30.0	30.0	30.00	30.0	30.0	30.1	30.03
35	35.0	35.0	35.0	35.00	35.0	35.0	35.0	35.00
40	40.0	40.0	40.1	40.03	40.0	40.1	40.0	40.03
45	45.0	45.0	45.1	45.03	45.0	45.0	45.1	45.03
50	50.2	50.2	50.2	50.20	50.1	50.2	50.2	50.17
55	55.2	55.2	55.2	55.20	55.2	55.2	55.2	55.20
60	60.2	60.1	60.2	60.17	60.2	60.2	60.2	60.20
65	65.2	65.2	65.2	65.20	65.2	65.1	65.2	65.17
70	70.2	70.2	70.1	70.17	70.2	70.1	70.2	70.17
75	75.1	75.2	75.2	75.17	75.2	75.1	75.2	75.17
80	80.2	80.2	80.2	80.20	80.2	80.2	80.1	80.17
85	85.2	85.1	85.2	85.17	85.1	85.1	85.2	85.13

Table D2 The correlation of the weight measured by each bathroom scale and the standard weight

		Average value of the weight on 1^{st} digital bathroom screen	Average value of the weight on 2^{nd} digital bathroom screen
Weight of standard pendulums	r	1.0	1.0
	p	<0.01	<0.01

Note: r = correlated value of the Pearson correlation

Appendix E

The intra-tester reliability tests for Berg Balance Scale (BBS), Functional Reach Test (FRT) and Timed Up and Go test (TUG)

Table E1 Raw data of the repeated tests of Berg Balance Scale (BBS), Functional Reach Test (FRT) and Timed Up and Go test (TUG)

Subjects	Berg Balance Scale		Functional Reach Test		Timed Up and Go test	
	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2
1	31	31	16.0	16.5	69.33	72.45
2	20	21	13.0	13.0	109.45	106.87
3	51	52	31.0	30.5	15.05	16.56
4	25	25	10.5	10.0	120.42	124.08
5	33	33	15.0	15.0	54.34	57.43
6	26	25	23.0	23.0	99.87	102.43
7	19	20	13.5	12.5	110.34	107.89
8	43	43	24.0	24.5	45.72	41.79
9	25	25	12.0	12.5	76.12	80.73
10	32	33	20.0	20.0	45.32	41.76

Table E2 The intra-tester reliability of Berg Balance Scale (BBS), Functional Reach Test (FRT) and Timed Up and Go test (TUG).

Test	ICC	95% CI
BBS	0.966	0.888 – 0.990
FRT	0.984	0.945 – 0.995
TUG	0.995	0.983 – 0.999

Note: ICC = Intraclass Correlation Coefficient of intra-tester reliability

Appendix F

The pilot study of weight shifting facilitation during standing by a balance training device developing from passive infrared sensor

Table F1 Raw data of the distance and percentage of body weight on left and right foot

Subjects	Distances	%BW on Lt. leg	%BW on Rt. leg	Subjects	Distances	%BW on Lt. leg	%BW on Rt. leg
1	2	48.66	50.00	6	2	54.09	51.63
	4	65.02	61.68		4	62.74	60.78
	6	80.57	82.68		6	78.99	80.23
	8	97.73	98.97		8	99.54	98.34
2	2	49.46	51.09	7	2	51.65	52.68
	4	66.25	67.36		4	58.84	63.61
	6	93.23	91.41		6	78.12	77.87
	8	96.04	97.61		8	97.41	99.39
3	2	48.56	52.35	8	2	50.41	49.89
	4	61.60	64.22		4	72.22	67.82
	6	76.02	79.55		6	84.70	83.04
	8	93.21	98.26		8	95.22	98.43
4	2	50.99	48.76	9	2	51.62	53.56
	4	65.72	67.90		4	66.92	68.70
	6	82.24	76.88		6	83.86	87.15
	8	98.78	97.54		8	96.67	98.77
5	2	51.29	49.86	10	2	52.01	50.40
	4	59.77	59.53		4	67.33	71.77
	6	73.02	79.13		6	86.16	90.93
	8	97.64	97.50		8	99.00	98.37

Table F2 The correlation between the distance of infrared sensor away from the left and the right sides of the subjects and the weight bearing on the subjects' leg during shift weight to left and right side that measured by the bathroom scales

		Weight bearing on left leg during shift weight to left side	Weight bearing on right leg during shift weight to right side
Distance of infrared sensor	r	0.849	0.856
	p-value	0.01**	0.01**

Note: r = correlated value of the Pearson correlation

Appendix G

Raw data of 24 subject

Subjects	Group	Age	Onset	MMSE	Brunnstrom	Type	MAS	BBS		DifBBS	%BW		Dif%BW	TUG		DifTUG	FRT		DiffRT
								Pre	Post		Pre	Post		Pre	Post		Pre	Post	
1	E	49	3	23	2	Ischemic	1	31	42	11	25.93	41.6	15.67	69.33	67	-2.33	16.33	18.33	2
2	E	65	1	30	1	Hemor	0	29	47	18	35.11	47.53	12.42	117.67	45	-72.67	15.33	20.33	5
3	E	65	4	30	3	Ischemic	0	51	54	3	36.43	42.83	6.4	16	11.33	-4.67	31	42	11
4	E	59	1	23	1	Hemor	0	25	40	15	30.36	24.15	-6.21	124	44.33	-79.67	10.33	18.67	8.34
5	E	52	2	30	2	Hemor	1+	33	40	7	36.32	44.11	7.79	54	25.87	-28.13	15.67	18.67	3
6	E	62	2	30	2	Ischemic	1+	40	48	8	17.85	40.21	22.36	34.01	30.24	-3.77	26.33	27	0.67
7	E	52	4	27	3	Ischemic	1+	44	47	3	32.47	48.86	16.39	24.2	29.61	5.41	24.33	31.33	7
8	E	61	4	25	3	Ischemic	2	43	49	6	26.29	42.18	15.89	61.05	58.36	-2.69	21.67	25.67	4
9	E	58	4	30	3	Ischemic	1+	25	36	11	24.67	41.54	16.87	78.12	39.78	-38.34	12.33	20.67	8.34
10	E	62	4	30	2	Ischemic	1	32	41	9	28.67	39.58	10.91	45.33	32.45	-12.88	20.13	25.67	5.54
11	E	63	3	30	2	Ischemic	1	43	48	5	37.03	50.8	13.77	43.72	23.94	-19.78	24	26.67	2.67
12	E	63	4	30	3	Ischemic	1	45	47	2	30.76	50.8	20.04	52.87	23.94	-28.93	26.67	26.67	0
13	C	63	4	29	3	Hemor	1	17	24	7	20.24	20.23	-0.01	121.33	127.33	6	21.33	9.67	-11.66
14	C	52	3	28	2	Ischemic	1+	39	29	-10	10.25	38.06	27.81	46.33	49.33	3	17.67	18	0.33
15	C	65	3	30	1	Hemor	0	48	49	1	37.4	36.59	-0.81	40.67	38.33	-2.34	22	22	0
16	C	53	2	30	2	Ischemic	1+	51	50	-1	39.57	42.02	2.45	15	15	0	35	19.67	-15.33
17	C	57	3	25	2	Ischemic	1	31	40	9	18.38	26.72	8.34	55	60.33	5.33	9.33	30.33	21
18	C	58	2	30	2	Ischemic	2	39	43	4	24.66	22.39	-2.27	44.67	38.67	-6	31.67	29	-2.67
19	C	60	1	29	1	Ischemic	0	40	42	2	26.5	19.51	-6.99	51.33	38.03	-13.3	21	21	0
20	C	65	2	30	2	Ischemic	1	20	27	7	23.12	20.73	-2.39	109.14	106.84	-2.3	13.67	13.67	0
21	C	63	3	30	1	Hemor	0	30	33	3	22.45	24.87	2.42	50.67	52.33	1.66	18.67	16.34	-2.33
22	C	57	5	30	3	Ischemic	1	27	31	4	18.67	19.33	0.66	37.43	36.87	-0.56	16.78	15.17	-1.61
23	C	55	2	30	1	Hemor	0	26	30	4	12.56	11.67	-0.89	101	96.87	-2.13	23.33	27	3.67
24	C	60	4	30	3	Hemor	1+	19	27	8	23.03	20.73	-2.3	110.67	106.33	-4.34	13.67	13.67	0

REFERENCES

Alawieh, A., Zhao, J., & Feng, W. (2018). Factors affecting post-stroke motor recovery: Implications on neurotherapy after brain injury. *Behav Brain Res, 340*, 94-101. doi:10.1016/j.bbr.2016.08.029

Andersen, K. K., Olsen, T. S., Dehlendorff, C., & Kammersgaard, L. P. (2009). Hemorrhagic and ischemic strokes compared: stroke severity, mortality, and risk factors. *Stroke, 40*(6), 2068-2072. doi:10.1161/strokeaha.108.540112

Bagley, P., Hudson, M., Forster, A., Smith, J., & Young, J. (2005). A randomized trial evaluation of the Oswestry Standing Frame for patients after stroke. *Clin Rehabil, 19*(4), 354-364. doi:10.1191/0269215505cr874oa

Batavia, M., Gianutsos, J. G., & Kambouris, M. (1997). An augmented auditory feedback device. *Arch Phys Med Rehabil, 78*(12), 1389-1392.

Bohannon, R. W. (1991). Relationship among paretic knee extension strength, maximum weight-bearing, and gait speed in patients with stroke. *J Stroke Cerebrovasc Dis, 1*(2), 65-69. doi:10.1016/s1052-3057(11)80003-0

Bohannon, R. W., Wolfson, L. I., & White, W. B. (2017). Functional reach of older adults: normative reference values based on new and published data. *Physiotherapy, 103*(4), 387-391. doi:10.1016/j.physio.2017.03.006

Bower, K. J., Clark, R. A., McGinley, J. L., Martin, C. L., & Miller, K. J. (2014). Clinical feasibility of the Nintendo Wii for balance training post-stroke: a phase II randomized controlled trial in an inpatient setting. *Clin Rehabil, 28*(9), 912-923. doi:10.1177/0269215514527597

Cheng, P. T., Wu, S. H., Liaw, M. Y., Wong, A. M., & Tang, F. T. (2001). Symmetrical body-weight distribution training in stroke patients and its effect on fall prevention. *Arch Phys Med Rehabil, 82*(12), 1650-1654. doi:10.1053/apmr.2001.26256

Cho, K. H., Lee, K. J., & Song, C. H. (2012). Virtual-reality balance training with a video-game system improves dynamic balance in chronic stroke patients. *Tohoku J Exp Med, 228*(1), 69-74.

Corriveau, H., Prince, F., Hebert, R., Raiche, M., Tessier, D., Maheux, P., & Ardilouze, J. L. (2000). Evaluation of postural stability in elderly with diabetic neuropathy. *Diabetes Care, 23*(8), 1187-1191.

Day, B. L., Guerraz, M., & Cole, J. (2002). Sensory interactions for human balance control revealed by galvanic vestibular stimulation. *Adv Exp Med Biol, 508*, 129-137.

de Haart, M., Geurts, A. C., Dault, M. C., Nienhuis, B., & Duysens, J. (2005). Restoration of weight-shifting capacity in patients with postacute stroke: a rehabilitation cohort study. *Arch Phys Med Rehabil, 86*(4), 755-762. doi:10.1016/j.apmr.2004.10.010

de Oliveira, C. B., de Medeiros, I. R., Frota, N. A., Greters, M. E., & Conforto, A. B. (2008). Balance control in hemiparetic stroke patients: main tools for evaluation. *J Rehabil Res Dev, 45*(8), 1215-1226.

De Weerdt, W. J. G., & Harrison, M. A. (1985). Problem List of Stroke Patients as Identified in the Problem Orientated Medical Record. *Australian Journal of Physiotherapy, 31*(4), 146-150.

Dettmann, M. A., Linder, M. T., & Sepic, S. B. (1987). Relationships among walking performance, postural stability, and functional assessments of the hemiplegic patient. *Am J Phys Med, 66*(2), 77-90.

Ding, Q., Stevenson, I. H., Wang, N., Li, W., Sun, Y., Wang, Q., . . . Wei, K. (2013). Motion games improve balance control in stroke survivors: A preliminary study based on the principle of constraint-induced movement therapy. *Displays, 34*(2), 125-131.

Dogan, A., Mengulluoglu, M., & Ozgirgin, N. (2011). Evaluation of the effect of ankle-foot orthosis use on balance and mobility in hemiparetic stroke patients. *Disabil Rehabil, 33*(15-16), 1433-1439. doi:10.3109/09638288.2010.533243

Dozza, M., Chiari, L., Chan, B., Rocchi, L., Horak, F. B., & Cappello, A. (2005). Influence of a portable audio-biofeedback device on structural properties of postural sway. *J Neuroeng Rehabil, 2*, 13. doi:10.1186/1743-0003-2-13

Dursun, E., Hamamci, N., Donmez, S., Tuzunalp, O., & Cakci, A. (1996). Angular biofeedback device for sitting balance of stroke patients. *Stroke, 27*(8), 1354-1357.

Dusica, S. P., Devecerski, G. V., Jovicevic, M. N., & Platisa, N. M. (2015). Stroke rehabilitation: Which factors influence the outcome? *Ann Indian Acad Neurol, 18*(4), 484-487. doi:10.4103/0972-2327.165480

Engardt, M., Ribbe, T., & Olsson, E. (1993). Vertical ground reaction force feedback to enhance stroke patients' symmetrical body-weight distribution while rising/sitting down. *Scand J Rehabil Med, 25*(1), 41-48.

Flansbjer, U. B., Blom, J., & Brogardh, C. (2012). The reproducibility of Berg Balance Scale and the Single-leg Stance in chronic stroke and the relationship between the two tests. *Pm r, 4*(3), 165-170. doi:10.1016/j.pmrj.2011.11.004

Flansbjer, U. B., Holmback, A. M., Downham, D., Patten, C., & Lexell, J. (2005). Reliability of gait performance tests in men and women with hemiparesis after stroke. *J Rehabil Med, 37*(2), 75-82. doi:10.1080/16501970410017215

Fowler, V., & Carr, J. (1996). Auditory feedback: effects on vertical force production during standing up following stroke. *Int J Rehabil Res, 19*(3), 265-269.

Goljar, N., Burger, H., Rudolf, M., & Stanonik, I. (2010). Improving balance in subacute stroke patients: a randomized controlled study. *Int J Rehabil Res, 33*(3), 205-210. doi:10.1097/MRR.0b013e328333de61

Gonzalez-Fernandez, M., Gil-Gomez, J. A., Alcaniz, M., Noe, E., & Colomer, C. (2010). eBaViR, easy balance virtual rehabilitation system: a study with patients. *Stud Health Technol Inform, 154*, 61-66.

Guyatt, G. H., Sullivan, M. J., Thompson, P. J., Fallen, E. L., Pugsley, S. O., Taylor, D. W., & Berman, L. B. (1985). The 6-minute walk: a new measure of exercise capacity in patients with chronic heart failure. *Can Med Assoc J, 132*(8), 919-923.

Hanlon, R. E. (1996). Motor learning following unilateral stroke. *Arch Phys Med Rehabil, 77*(8), 811-815.

Jack, D., Boian, R., Merians, A. S., Tremaine, M., Burdea, G. C., Adamovich, S. V., . . . Poizner, H. (2001). Virtual reality-enhanced stroke rehabilitation. *IEEE Trans Neural Syst Rehabil Eng, 9*(3), 308-318. doi:10.1109/7333.948460

Jung, K., Kim, Y., Chung, Y., & Hwang, S. (2014). Weight-shift training improves trunk control, proprioception, and balance in patients with chronic hemiparetic stroke.

Tohoku J Exp Med, 232(3), 195-199.

Lee, M. Y., Wong, M. K., & Tang, F. T. (1996). Using biofeedback for standing-steadiness, weight-bearing training. *IEEE Engineering in Medicine and Biology Magazine, 15*(6), 112-116. doi:10.1109/51.544518

Li, Z., Han, X. G., Sheng, J., & Ma, S. J. (2016). Virtual reality for improving balance in patients after stroke: A systematic review and meta-analysis. *Clin Rehabil, 30*(5), 432-440. doi:10.1177/0269215515593611

Magill, R., & Anderson, D. I. (2017). *Motor learning and control : concepts and applications*.

Mancini, M., & Horak, F. B. (2010). The relevance of clinical balance assessment tools to differentiate balance deficits. *Eur J Phys Rehabil Med, 46*(2), 239-248.

Mao, H. F., Hsueh, I. P., Tang, P. F., Sheu, C. F., & Hsieh, C. L. (2002). Analysis and comparison of the psychometric properties of three balance measures for stroke patients. *Stroke, 33*(4), 1022-1027.

Marie Cameron, D. (1999). *Movement analysis of individuals with hemiparesis and individuals who are neurologically intact during sit-to-stand and stepping-up-a-curb*.

Merians, A. S., Jack, D., Boian, R., Tremaine, M., Burdea, G. C., Adamovich, S. V., . . . Poizner, H. (2002). Virtual reality-augmented rehabilitation for patients following stroke. *Phys Ther, 82*(9), 898-915.

Mudie, M. H., Winzeler-Mercay, U., Radwan, S., & Lee, L. (2002). Training symmetry of weight distribution after stroke: a randomized controlled pilot study comparing task-related reach, Bobath and feedback training approaches. *Clin Rehabil, 16*(6), 582-592. doi:10.1191/0269215502cr527oa

Nyberg, L., & Gustafson, Y. (1995). Patient falls in stroke rehabilitation. A challenge to rehabilitation strategies. *Stroke, 26*(5), 838-842.

Outermans, J. C., van Peppen, R. P., Wittink, H., Takken, T., & Kwakkel, G. (2010). Effects of a high-intensity task-oriented training on gait performance early after stroke: a pilot study. *Clin Rehabil, 24*(11), 979-987. doi:10.1177/0269215509360647

Peterka, R. J. (2002). Sensorimotor integration in human postural control. *J Neurophysiol, 88*(3), 1097-1118. doi:10.1152/jn.2002.88.3.1097

Sacco, R. L., Kasner, S. E., Broderick, J. P., Caplan, L. R., Connors, J. J., Culebras, A., . . . Vinters, H. V. (2013). An updated definition of stroke for the 21st century: a statement for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke, 44*(7), 2064-2089. doi:10.1161/STR.0b013e318296aeca

Sackley, C. M., & Lincoln, N. B. (1997). Single blind randomized controlled trial of visual feedback after stroke: effects on stance symmetry and function. *Disabil Rehabil, 19*(12), 536-546.

Sawacha, Z., Carraro, E., Contessa, P., Guiotto, A., Masiero, S., & Cobelli, C. (2013). Relationship between clinical and instrumental balance assessments in chronic post-stroke hemiparesis subjects. *J Neuroeng Rehabil, 10*, 95. doi:10.1186/1743-0003-10-95

Shumway-Cook, A., & Woollacott, M. H. (2001). *Motor Control: Theory and Practical Applications*: Lippincott Williams & Wilkins.

Song, Y. B., Chun, M. H., Kim, W., Lee, S. J., Yi, J. H., & Park, D. H. (2014). The effect of virtual reality and tetra-ataxiometric posturography programs on stroke patients with impaired standing balance. *Ann Rehabil Med, 38*(2), 160-166. doi:10.5535/arm.2014.38.2.160

Talvitie, U. (2000). Socio-affective characteristics and properties of extrinsic feedback in physiotherapy. *Physiother Res Int, 5*(3), 173-189.

Tsaklis, P. V., Grooten, W. J., & Franzen, E. (2012). Effects of weight-shift training on balance control and weight distribution in chronic stroke: a pilot study. *Top Stroke Rehabil, 19*(1), 23-31. doi:10.1310/tsr1901-23

Tutuarima, J. A., van der Meulen, J. H., de Haan, R. J., van Straten, A., & Limburg, M. (1997). Risk factors for falls of hospitalized stroke patients. *Stroke, 28*(2), 297-301.

van Vliet, P. M., & Wulf, G. (2006). Extrinsic feedback for motor learning after stroke: what is the evidence? *Disabil Rehabil, 28*(13-14), 831-840.

doi:10.1080/09638280500534937

Walker, C., Brouwer, B. J., & Culham, E. G. (2000). Use of visual feedback in retraining balance following acute stroke. *Phys Ther, 80*(9), 886-895.

Winstein, C. J., Merians, A. S., & Sullivan, K. J. (1999). Motor learning after unilateral brain damage. *Neuropsychologia, 37*(8), 975-987.

จารุวาระกูล, ฐ. (2548). การสอบเทียบเครื่องชั่ง. กรุงเทพมหานคร: กลุ่มวิเคราะห์ สำนักอุตสาหกรรมพื้นฐาน กรมอุตสาหกรรมพื้นฐานและการเหมืองแร่กรุงเทพฯ.

ฝ่ายห้องปฏิบัติการสถาบันบริการตรวจสอบคุณภาพและมาตรฐานผลิตภัณฑ์. (2555). แนวทางปฏิบัติในการตรวจสอบ ทวนสอบ และสอบเทียบเครื่องชั่ง. เชียงใหม่: มหาวิทยาลัยแม่โจ้

VITA

NAME	Thipwimon Sillapachai
DATE OF BIRTH	8 Aug 1987
PLACE OF BIRTH	Samutprakan
INSTITUTIONS ATTENDED	Bachelor of science (Physical Therapy): Huachiew Chalermprakiet University
HOME ADDRESS	775 M.4 Samrongnuea, Mueang, Samutprakan, 10270