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Research Article

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Effects of Pressure Sense Perception Training on Unstable Surface on Somatosensory, Balance and Gait Function in Patients with Stroke

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| Abstract |

PURPOSE: This study aimed to investigate the effects of pressure sense perception training (PSPT) on various surfaces on the somatosensory system, balance, and walking ability in chronic stroke patients.

METHODS: Thirty patients with stroke participated in this study and were randomly assigned to one of three groups; group 1 received the general physical therapy and the PSPT on a stable surface, group 2 received the general physical therapy and the PSPT on an unstable surface, and group 3 received the general physical therapy alone. Participants in group 1 and group 2 underwent 30 min/session, 3 days per week, for 4 weeks. Pressure error (PE) was used to evaluate changes of proprioception. The Balancia, Functional reach test (FRT), and Timed Up and Go (TUG) were used to assess the balance ability, and the 10m Walking Test (10-MWT) was used to assess walking ability.

RESULTS: Experimental groups (group 1 and group 2) showed significant differences in PE, FRT, TUG, and 10-MWT compared to the control group ($p < 0.05$). Group 2 (PSPT on an unstable surface) was significantly different in PE, FRT, and 10-MWT from group 1 ($p < 0.05$). No significant differences were observed for other measures.

CONCLUSION: Pressure sense perception training on an unstable surface might be a significantly more effective method for improving somatosensory function, balance, and walking ability, than PSPT on a stable surface.

Key Words: Sensorimotor training, Balance ability, Walking ability, Pressure sense perception

Ⅰ. Introduction

Most stroke survivors suffer from impaired motor function in the lower extremities (Bang et al, 2014). The impaired lower limb is typically weak, slow, lacks coordination, and may show spasticity. What patients desire most among the limitations of activities of daily living (ADL) is improvement in walking ability (Rosen et al, 2005), since it is necessary for daily life and social participation (Macko et al, 2008). Balance ability is an important factor for independent walking in stroke patients (Kusoffsky et al, 2001), as previous studies on walking intervention in stroke

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have in stroke have reported (Mentiplay et al, 2015; Rodrigues-Baroni et al, 2014). Various walking intervention protocols based on balance ability have been designed and evaluated (Park and Hwangbo, 2015).

Balance is divided into static and dynamic balance. Static balance is maintained without movement. Dynamic balance is maintained through stimulation from the external environment (Geurts et al, 2005; Ragnarsdóttir, 1996). Sensory disturbance, and limited motor control may determine asymmetrical walking or standing, leading to decreased balance ability and increased risk of falling (Cheng et al, 2001). Thus, improvement of balance ability improves the quality of life and social participation (Hendrickson et al, 2014; Marigold and Eng, 2006). Typically, individuals derive sensory input from the visual, vestibular, and somatosensory systems for balance control (Cheng et al, 2001). Weight bearing ability of stroke patients was less for the affected side compared with the less affected side. Also sensory problems are difficult to weight shifting (Eng and Chu, 2002; Goldie et al, 1996). In the previous studies, the most effective method for improving the balance ability in patients with stroke was to improve the impaired somatosensory system (Ju and Yoo, 2014; Silva et al, 2015). The method of somatosensory improvement consists of the affected side on a stable surface while the less affected side is on an unstable surface (Ju and Yoo, 2014). In a study by Ahmed (2011), the training protocol was composed of a step by step regimen of sitting, standing, and standing with one leg on an unstable surface. This study showed improvement in balance. Proprioception is involved position, movement, force, weight, pressure et al (Stillman, 2002). Proprioceptive training is focus on proprioceptive sense. Proprioceptive training is an intervention that the improved of sensorimotor or somatosensory performance (Aman et al, 2014). The purpose of pressure sense perception training (PSPT) is to acquire postural stability during rest and motion. Sway around the center of gravity is the index thought to most directly reflect postural stability.

However, little is known about the effects of PSPT on an unstable surface on the changes in somatosensory ability of stroke patients. The purpose of this study was to investigate and evaluate the effects of PSPT on somatosensory system, balance, and walking ability in chronic stroke patients, on various surfaces.

Ⅱ. Methods

1. Participants

All subjects were patients with chronic stroke undergoing hospital rehabilitation, and independent standing maintenance. The analysis included thirty patients (20 men and 10 women) with no missing data on the outcome measure. Table 1 outlines the baseline characteristics of the participants. The inclusion criteria were: (1) experienced a unilateral stroke at least 6 months post event or more, (2) able to maintain a standing position on the balance mat over 30 seconds, (3) capable of standing without any assistance over 30 seconds, (4) not training in any interventions from other institutions, and (5) sufficient cognition to participate in the training, that is, a Mini-Mental State Exam (MMSE) score of 24 or higher (Park and Kwon, 1989), (6) Semmes-Weinstein monofilaments test, size up to 5.07 discrimination of the foot pressure. The 5.07 monofilament is detected protect sense of threshold (Feng et al, 2009). The exclusion criteria were: (1) any comorbidity or disability other than the stroke that precludes training, and (2) any uncontrolled health conditions for which training is contradicted. The study was approved by the Daejeon University institutional review board, and all participants provided informed consent.

2. Study design

This study was a double-blinded, randomized controlled design. Participants were randomized into three groups (directly after the test) by a physical therapist not involved in the study. All of the enrolled patients were randomly assigned to 1 of 3 groups using a table of random numbers; group 1 received general physical therapy and the PSPT on a stable surface, group 2 received general physical therapy and the PSPT on an unstable surface, and group 3 received general physical therapy alone.

3. Procedure

Subjects in the three groups participated in a rehabilitation program consisting of physiotherapy and occupational therapy during a 60-min session, 5 days per week, for 4 weeks. In addition, the experimental group (group 1 on the stable surface and group 2 on the unstable surface (balance pad) participated in the PSPT described below. Participants in experimental groups (group 1 and group 2) underwent 30 min/session, 3 days per week, for 4 weeks.

1) Pressure sense perception training

The therapist measured the minimum and maximum pressure of the more affected side before training, for the subjects of the experimental groups (group 1 and group 2). Participants were asked to keep both feet parallel at 100 mm distance, and to conduct a forward weight shift in the standing position. Participants were then asked to shift weight forward to the more affected side. After weight shifting, this position was maintained for 5 seconds. When the participants were tired, they had a break of 3 minutes in the sitting position (Goldie et al, 1996). The forefoot on both sides was attached to foam (50 cm × 41 cm × 6 cm) (group 1 was assigned stable foam and group 2 was assigned balance pad). The foam (stable and unstable) was considered to be equal to the height:weight ration. Pressure is measured into the heel in order to avoid compensatory plantar flexion. Knee joint of the more affected side shows slight flexion. Immediately after the subject’s response, verbal feedback was obtained if it fail to test reproduced the pressure. Each training session was performed step by step. For the PSPT, we used the pressure error (stage 1 and stage 2). Before training, participants were measured both at minimum and maximum pressure. Minimum pressure was measured when training in a standing position. Maximus pressure was measured when training position with weight bearing to affected side. Therapists set up the target weight which was between minimum pressure and maximum pressure. Stage 1 is trained by pressing the scales lower than the average of the minimum and maximum pressure. Stage 2 is trained by pressing the scales higher than the average of the minimum and maximum pressure. In case that the error from the target weight was within 1kg, it was marked as 60% successful and proceeded to the next stage (Byun, 2014).

2) General physical therapy

Subjects in the three groups participated in a rehabilitation program consisting of physiotherapy, which included ordinary postural control exercises, such as maintenance of standing, and shift of the weight loads to both sides.

4. Outcome measures

Pressure error was used to evaluate the changes in proprioception. The Balancia, Functional reach test (FRT), and Timed Up and Go (TUG) were used to assess the balance ability; the 10-M Walking Test (10-MWT) was used to assess walking ability.

Pressure error (PE) (stage 1 and stage 2) was measured using a hand-held Dynamometer. Pressure error in stage 1 and stage 2 was measured 3 times and the mean of pressure error was recorded. Measurements were done while participants kept their eyes closed in supine position (Kang et al, 2013). Kim et al. (2014) studies method were used joint position sense, force sense to proprioception measurement.

The Balancia uses the Wii balance board (WBB)

Table 1. Demographic data of the participants

	PSPT on a stable surface group (n=10)	PSPT on an unstable surface group (n=10)	Control group (n=10)	χ^2/F
Gender (n)				
Male	4	8	8	0.01
Female	6	2	2	
Side of stroke (n)				
Right	3	4	5	0.66
Left	7	6	5	
Type of stroke (n)				
Infarction	4	4	3	0.87
Hemorrhage	6	6	7	
Time after stroke (month)	42.20(21.61)	37.80(22.40)	50.70(13.83)	0.34
Age (years), mean (SD)	54.70(3.09)	59.40(8.63)	56.40(11.87)	0.48
MMSE (scores), mean (SD)	26.10(1.96)	26.60(1.71)	26.30(2.03)	0.85

NOTE. Baseline demographic data for participants include in the three different groups and significance level at $p<0.05$ for difference between the groups.
Abbreviations: PSPT, pressure sense perception training; MMSE, mini-mental state examination.

(Nintendo, Kyoto, Japan). The WBB was used to measure static balance. The WBB collects Center of Pressure (COP) information of the load cell located at the four corners of a 50 cm × 50 cm rectangle and transfers the information to a computer via Bluetooth. The Balancia program (Balancia 2.0, Mintosys, Korea) was used in standing position to analyze the COP of the path-length and velocity average. Participants were asked to take up a comfortable standing position, with a distance between heels of 5~6cm, during WBB measurements (Lisiński et al, 2012; Park et al, 2013). The measurements were taken 3 times in the standing position, with each measurement lasting 30 seconds.

The FRT is measured by the maximal reaching distance in the front and metacarpal phalangeal joint (Newton, 2001). If participants could not reach, the acromion distance was measured. The participants were asked to stand 3 times, and the average forward distance time was recorded.

The TUG was used as a dynamic balance test. This test records the time taken to rise from a chair (height: 50 cm), walk 3 m, turn around a marker, walk back to the chair, and sit down. The participants were asked to walk 3 times, and the average round-trip time was recorded. A 10-MWT was performed by walking 10 m to measure the gait speed (Van Loo et al, 2004). The walkway was 14 m long, including a 2-m section for acceleration and a 2-m section for deceleration, and it has been used in other studies. The participants were asked to walk as fast and as safely as they could. Gait speed was measured with a stop watch. The participants were asked to walk 3 times, and the mean round-trip time was recorded.

5. Data analysis

SPSS 18.0 for Windows (Chicago, IL, USA) was used for statistical analysis. The Kruskal-Wallis test or a 1-way analysis of variance was used to assess the homogeneity between groups before the study. Because outcome measurement data showed parametric distributions, the paired t-test was used to compare data obtained before and after treatment in each group. The 1-way analysis of variance was followed by a Scheffe post-hoc test for comparison of significant differences among groups. All statistical tests were completed at the 0.05 alpha level.

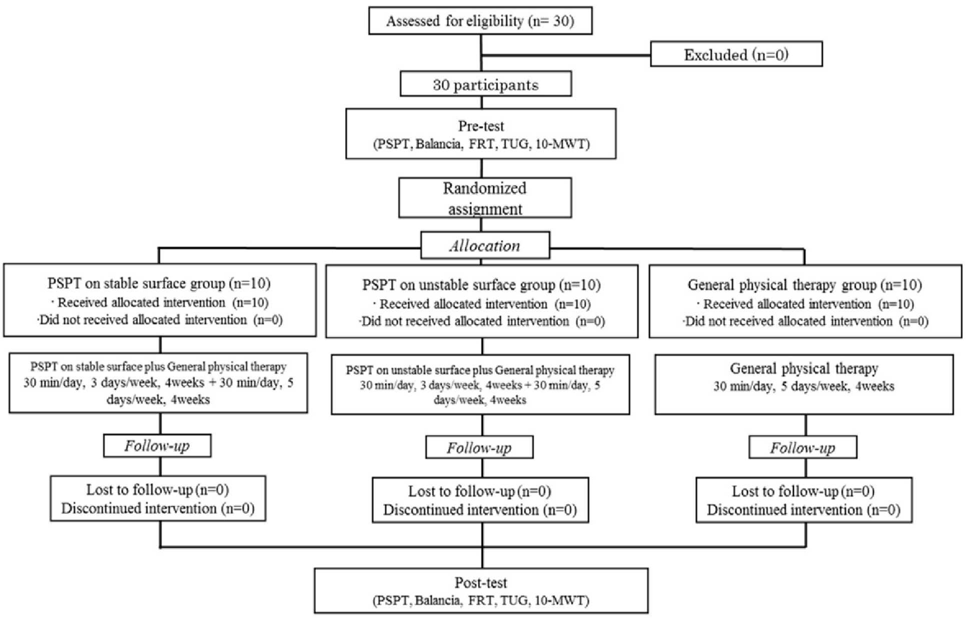

Fig. 1. Flow diagram

Balancia conclude the static balance (path-length, velocity average).

Abbreviations: PSPT, pressure sense perception training; FRT, functional reach test; TUG, time up and go test; 10-MWT, 10m walk test.

Ⅲ. Results

Thirty people fulfilled the criteria and voluntarily agreed to participate in this study. All participants completed the entire study. There were no significant differences in the age, duration of onset, sex, side of stroke, type of stroke, and MMSE (Table 1). The three groups were not significantly different in the pressure error (PE) (stage 1 F=2.95, $p>0.05$ and stage 2 F=0.76, $p>0.05$), Balancia (path-length F=1.43, $p>0.05$ and velocity average F=0.18, $p>0.05$), FRT (F=0.31, $p>0.05$), TUG (F=1.87, $p>0.05$), and 10-MWT (F=3.32, $p>0.05$) in the pre-test (Table 2). The study was conducted 30 min/day, 3 days a week, for 4 weeks. All procedures are shown in the flow diagram (Fig. 1). There were significant differences among the groups for all tests between the pre- and post- test. Table 2 shows the results of participants in PE, Balancia, FRT, TUG, and 10-MWT. The experimental groups (group 1 and group 2) had significantly higher differences than the control group in PE, Balancia, FRT, and 10-MWT ($p<0.05$) (Table 2). Group 2 showed a significant difference from group 1 in PE, Balancia (velocity average), FRT, TUG, and 10-MWT ($p<0.05$).

Ⅳ. Discussion

This study was conducted to investigate the effect of PSPT on various surfaces in patients with chronic stroke. PSPT is a special program aimed at motor control through sensory input to improve balance. The study revealed that experimental groups (group 1 and group 2) showed significant differences in the pressure error (PE), Balancia (path-length, velocity average), FRT, TUG, and 10-MWT,

Table 2. Descriptive measurements.

Variables	Group 1 (n=10)		Group 2(n=10)		Group 3 (n=10)		*F*
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	
Stage 1 Pressure error	6.85(2.28)	1.90(1.90)*†	8.71(1.95)	1.55(1.33)*§	6.85(1.64)	5.44(1.63)*‡	32.79
Stage 2 Pressure error	6.99(2.46)	1.88(1.06)*†	8.17(3.23)	2.39(1.60)*§	8.32(2.09)	6.76(2.36)*‡	8.50
Balanacia							
Path-Length (cm)	85.30(7.54)	71.59(6.95)*	92.37(12.79)	73.08(10.21)*§	78.94(26.94)	84.36(10.87)*‡	7.69
Velocity average (cm/s)	8.54(1.52)	4.49(0.97)*†	9.05(1.67)	2.61(0.75)*§	8.76(2.51)	6.77(1.61)*‡	35.05
FRT (cm)	5.99(2.40)	9.99(2.53)*†	6.90(3.53)	14.28(4.26)*§	7.05(3.75)	8.93(4.68)*‡	46.64
TUG(m/s)	28.36(12.69)	24.75(12.17)*†	19.90(3.78)	13.15(3.78)*§	27.09(12.43)	24.87(11.37)*	25.45
10-MWT(m/s)	27.56(9.86)	23.17(10.01)*†	17.74(3.10)	11.90(3.16)*§	25.33(11.52)	23.96(11.26)*‡	34.03

[a]Means (SD); *Significant difference within groups($p<0.05$); †Significant difference between Group1 and Group2 ($p<0.05$.); ‡Significant difference between Group1 and Group3 ($p<0.05$); §Significant difference between Group2 and Group3 ($p<0.05$).
Pre-test was performed before the intervention, and post-test was performed after 4 weeks.
Abbreviations: FRT, Functional reaching test; TUG, Time up and go test; 10-MWT, 10m walk test; Group1, Pressure sense perception on stable surface group; Group2, Pressure sense perception on unstable surface group; Group3, General physical therapy group; Stage 1 Pressure error, pressing error in lower range than the average value; Stage 2 Pressure error, pressing error in higher range than the average value.

compared to the control group after intervention. Group 2 (unstable surface) showed a significant difference from group 1 (stable surface) in PE, Balancia (velocity average), FRT, TUG, and 10-MWT. PSPT effectively improved the PE, balance, and walking ability. Furthermore, PSPT on the unstable surface suggests that this is an efficacious method to improve the somatosensory function, balance, and walking ability in chronic stroke patients.

The results of this study showed a better improvement in the PSPT groups on the PE, balance, and walking ability than the control group. PE was used as a somatosensory test. Pressure sense has been defined as sensory information accepted through the exteroceptors of the somatosensory system (Stillman, 2002). In the study of Hertel et al (1996), significant improvement in balance ability and decrease in the joint position sense error was reported. The Jung et al (2014) studies reported that weight shifting training on an unstable surface might improve reposition sense. Our study is in agreement with the results of these studies.

PSPT was conducted in standing position for training with foot pressure sensation feedback, with resultant improvement in balance and walking ability (Morioka and Yagi, 2003). The reason for the improvement in motor performance such as balance and walking ability, may be inferred from the following: PSPT through the conscious control stage is clinched via the cortex and pyramidal tract. Also, In the previous study, participants received auditory feedback about pressure during weight bearing to the affected side, showed improvement in TUG (Ki et al, 2015). The effect of transfer of learning is conceivable as well. Therefore, it may be that the improved PE decreased the swaying in a standing position.

Postural control depends on somatosensory from foot (Ju and Yoo, 2014; Shumway-Cook et al, 1988). Unstable surface provide outward sway and change postural orientation ability. Also it help to postural strategy (Lee and Roh, 2011). Exercise of the unstable surface was facilitation of proprioceptive, it is more effective than a stable surface (Lee et al, 2014; Cho, 2011). In the study of Geiger et al (2001) weight shift training on the balance board with eyes closed or open, showed improvement in TUG. In this study, Experimental groups (group 1 and group 2) trained for the weight shift task on a stable or unstable surface. The result of this study seems to indicate improved balance ability. Furthermore, during weight shifting training, the therapist discussed with participants the degree of pressure, using feedback that might affect their weight shifting ability.

This study has some limitations. First, a major limited factor in generating our results to the entire stroke patients is probably the small sample size. Second, absence of follow-up after the end of intervention did not allow for determination of the durability of effects. Therefore, conduct of further studies, including large sample sizes and long-term follow-up assessment are required in order to evaluate the effects of PSPT.

Ⅴ. Conclusion

This study was conducted in order to evaluate the effect of PSPT on an unstable surface in patients with chronic stroke. The results of PSPT improved somatosensory function, balance, and walking ability; with significantly better outcome in training on an unstable surface than a stable surface. Thus, PSPT was successfully applied for clinical rehabilitation. Improving the balance ability in stroke patients is a very important factor for the quality of daily life and social participation, as well as walking ability. PSPT with an anterior weight shift protocol showed clinical advantage, as it was more difficult for stroke patients to perform lateral weight shift than forward weight shift.

References

Ahmed AF. Effect of sensorimotor training on balance in elderly patients with knee osteoarthritis. J Adv Res. 2011; 2(4):305-11.

Aman JE, Elangovan N, Yeh IL, et al. The effectiveness of proprioceptive training for improving motor function: a systematic review. Front Hum Neurosci. 2014; 8:1075.

Bang DH, Shin WS, Noh HJ, et al. Effect of unstable surface training on walking ability in stroke patients. J Phys Ther Sci. 2014;26(11):1689-91.

Byun DU. The Effect of Pressure Sense Perception Training for The Static and Dynamic Balance Ability on Stroke Patients. Master's Degree. Daejeon University. 2014.

Cheng PT, Wu SH, Liaw MY, et al. Symmetrical body-weight distribution training in stroke patients and its effect on fall prevention. Arch Phys Med Rehabil. 2001;82 (12):1650-4.

Cho MJ. Do unstable surface facilitate proprioception input? Somatosensory evoked potentials analysis study. Master’s Degree. Catholic University of Pusan. 2011.

Eng JJ, Chu KS. Reliability and comparison of weight-bearing ability during standing tasks for individuals with chronic stroke. Arch Phys Med Rehabil. 2002;83(8): 1138-44.

Feng Y, Schlösser FJ, Sumpio BE. The Semmes Weinstein monofilament examination as a screening tool for diabetic peripheral neuropathy. J Vasc Surg. 2009;50 (3):675-82.

Geiger RA, Allen JB, O'Keefe J, et al. Balance and mobility following stroke: effects of physical therapy interventions with and without biofeedback/forceplate training. Phys Ther. 2001;81(4):995-1005.

Geurts AC, de Haart M, van Nes IJ, et al. A review of standing balance recovery from stroke. Gait Posture. 2005;22(3): 267-81.

Goldie PA, Matyas TA, Evans OM, et al. Maximum voluntary weight-bearing by the affected and unaffected legs in standing following stroke. Clin Biomech (Bristol, Avon). 1996;11(6):333-42.

Hendrickson J, Patterson KK, Inness EL, et al. Relationship between asymmetry of quiet standing balance control and walking post-stroke. Gait Posture. 2014;39(1): 177-81.

Hertel JN, Guskiewicz KM, Kahler DM, et al. Effect of lateral ankle joint anesthesia on center of balance, postural sway, and joint position sense. J Sport Rehabil. 1996;5:111-9.

Park JH, Kwon YC. Standardization of Korean Version of the Mini-Mental State Examination(MMSE-K) for Use in the Elderly. Part II. Diagnostic Validity. Kor Neuropsychia Assoc. 1989;28(3):508-13.

Ju SK, Yoo WG. The Effect of Somatosensory and Cognitive-motor Tasks on the Paretic Leg of Chronic Stroke Patients in the Standing Posture. J Phys Ther Sci. 2014;26(12):1869-70.

Jung K, Kim Y, Chung Y, et al. Weight-Shift Training Improves Trunk Control, Proprioception, and Balance in Patients with Chronic Hemiparetic Stroke. Tohoku J Exp Med. 2014;232(3):195-9.

Kang DH, Yu IY, Lee GC. The Effects of Knee Extensor, Flexor Muscle Strength and Joint Position Sense in Squat Exercise on Variety Surface. Kor Soc Int Med. 2013;1(2):47-57.

Ki KI, Kim MS, Moon Y, et al. Effects of auditory feedback during gait training on hemiplegic patients' weight bearing and dynamic balance ability. J Phys Ther Sci. 2015;27(4):1267.

Kim CY, Choi JD, Kim HD. No correlation between joint position sense and force sense for measuring ankle proprioception in subjects with healthy and functional ankle instability. Clin Biomech. 2014;29(9):977-83.

Kusoffsky A, Apel I, Hirschfeld H. Reaching-lifting-placing task during standing after stroke: Coordination among ground forces, ankle muscle activity, and hand movement. Arch Phys Med Rehabil. 2001;82(5):650-60.

Lee HK, Lee JC, Song GH. The Effects of Rhythmic Sensorimotor Training in Unstable Surface on Balance Ability of Elderly Women. J Korean Soc Phys Med. 2014;9(2):181-91.

Lee JY, Roh HL. Comparison of Balance Ability between Stable and Unstable Surfaces for Chronic Stroke Patients. Kor Aca-Ind Coop Soc. 2011;12(8):3587-93.

Lisiński P, Huber J, Gajewska E, et al. The body balance training effect on improvement of motor functions in paretic extremities in patients after stroke. A randomized, single blinded trial. Clin Neurol Neurosurg. 2012;114(1):31-6.

Macko RF, Benvenuti F, Stanhope S, et al. Adaptive physical activity improves mobility function and quality of life in chronic hemiparesis. J Rehabil Res Dev. 2008;45(2):323-8.

Marigold DS, Eng JJ. The relationship of asymmetric weight-bearing with postural sway and visual reliance in stroke. Gait Posture. 2006;23(2):249-55.

Mentiplay BF, Adair B, Bower KJ, et al. Associations between lower limb strength and gait velocity following stroke: A systematic review. Brain Inj. 2015;29(4):409-22.

Morioka S, Yagi F. Effects of perceptual learning exercises on standing balance using a hardness discrimination task in hemiplegic patients following stroke: a randomized controlled pilot trial. Clin Rehabil. 2003;17(6):600-7.

Newton RA. Validity of the multi-directional reach test: a practical measure for limits of stability in older adults. J Gerontol A Biol Sci Med Sci. 2001;56(4):M248-52.

Park DS, Lee DY, Choi SJ, et al. Reliability and Validity of the Balancia using Wii Balance Board for Assessment of Balance with Stroke Patients. Kor Aca-Ind Coop Soc. 2013;14(6):2767-72.

Park EC, Hwangbo G. The effects of action observation gait training on the static balance and walking ability of stroke patients. J Phys Ther Sci. 2015;27(2):341-4.

Ragnarsdóttir M. The concept of balance. Physiotherapy. 1996;82(6):368-75.

Rodrigues-Baroni JM, Nascimento LR, Ada L, et al. Walking training associated with virtual reality-based training increases walking speed of individuals with chronic stroke: systematic review with meta-analysis. Braz J Phys Ther. 2014;18(6):502-12.

Rosen E, Sunnerhagen KS, Kreuter M. Fear of falling, balance, and gait velocity in patients with stroke. Physiother Theory Pract. 2005;21(2):113-20.

Shumway-Cook A, Anson D, Haller S. Postural sway biofeedback: its effect on reestablishing stance stability in hemiplegic patients. Arch Phys Med Rehabil. 1988;69(6):395-400.

Silva P, Botelho PFFB, de Oliveira Guirro EC, et al. Long-term benefits of somatosensory training to improve balance of elderly with diabetes mellitus. J Bodyw Mov Ther. 2015;19(3):453-7.

Stillman BC. Making sense of proprioception: the meaning of proprioception, kinaesthesia and related terms. Physiotherapy. 2002;88(11):667-76.

Van Loo M, Moseley A, Bosman J, et al. Test-re-test reliability of walking speed, step length and step width measurement after traumatic brain injury: a pilot study. Brain Inj. 2004;18(10):1041-8.