ผลการฝึกการทรงตัวภายใต้สถานการณ์ที่มีการเปลี่ยนข้อมูลรับความรู้สึกในผู้ป่วยโรคหลอดเลือดสมอง: การทบทวนเอกสารอย่างเป็นระบบจากผลงานวิจัยชนิดการวิจัยเชิงทดลองแบบสุ่มและมีกลุ่มควบคุม

Effect of Sensory Organization Training on Improving Balance Performance in Stroke Patients- A Systematic Review of Randomized Controlled Trials

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บทคัดย่อ

ที่มา: จากรายงานวิจัยที่ผ่านมายังไม่มีพบการทบทวนเอกสารอย่างเป็นระบบเพื่อประเมินประสิทธิภาพของโปรแกรมการฝึกการทรงตัวภายใต้สถานการณ์ที่มีการเปลี่ยนข้อมูลรับความรู้สึกในผู้ป่วยโรคหลอดเลือดสมอง วัตถุประสงค์: เพื่อประเมินประสิทธิภาพของโปรแกรมการฝึกการทรงตัวภายใต้สถานการณ์ที่มีการเปลี่ยนข้อมูลรับความรู้สึกในผู้ป่วยโรคหลอดเลือดสมอง วิธีการ: ทำการสืบค้นและทบทวนเอกสารอย่างเป็นระบบจากฐานข้อมูลอิเล็กทรอนิกส์ 7 แห่งได้แก่ PubMed, MEDLINE, CINAHL, OVID, ScienceDirect, Cochrane Library และ PEDro ในช่วงเดือนกันยายน ปี พ.ศ. 2554 โดยคัดเลือกผลงานวิจัยชนิดการวิจัยเชิงทดลองแบบสุ่มและมีกลุ่มควบคุมที่เกี่ยวกับโปรแกรมการฝึกการทรงตัวภายใต้สถานการณ์ที่มีการเปลี่ยนข้อมูลรับความรู้สึกในผู้ป่วยโรคหลอดเลือดสมองที่มีอายุ ≥ 18 ปี การประเมินคุณภาพงานวิจัยใช้การประเมินความเสี่ยงต่อการเกิดอคติที่พัฒนามาจาก van Tulder scale ที่แนะนำโดย Cochrane Handbook of Review of Interventions การสรุปผลประสิทธิภาพของโปรแกรมการฝึกใช้วิธี GRADE approach ที่แนะนำโดย Cochrane Back Review Group ผลการศึกษาและสรุปผลการศึกษา: มีผลงานวิจัยเข้าเกณฑ์การคัดเลือกทั้งหมด 3 เรื่อง โดยมีจำนวนผู้เข้าร่วมวิจัยทั้งหมด 104 คน ส่วนใหญ่เป็นผู้ป่วยโรคหลอดเลือดสมองในระยะเรื้อรัง ผลศึกษาที่มีคุณภาพระดับปานกลาง แสดงให้เห็นว่าโปรแกรมดังกล่าวไม่มีอันตรายต่อผู้ป่วยอาจ สามารถเพิ่มความสามารถในการเลือกใช้ข้อมูลจากระบบรับความรู้สึกที่เหมาะสมในการควบคุมการทรงตัวและเพิ่มคุณภาพชีวิตในผู้ป่วยโรคหลอดเลือดสมองได้ แต่อย่างไรก็ตาม ผลในการเพิ่มขอบเขตความมั่นคงและความสามารถในการทรงตัวในขณะทำกิจกรรมไม่ต่างจากโปรแกรมการฝึกทรงตัวทั่วไป

คำสำคัญ: *การทรงตัว ผู้ป่วยโรคหลอดเลือสมอง การฟื้นฟู การประสานสัมพันธ์ระหว่างระบบรับความรู้สึกและระบบประสาทยนต์*

Abstract

Balance training program that included the sensory organization training aimed to treat the sensory reweighting impairment in persons with stroke, but its effectiveness had not been evaluated. The objective of the study was to evaluate the effectiveness of sensory organization training on improving balance performance in patients with stroke. To start the research procedure, studies published before September 2011 was searched using seven database; including PubMed, MEDLINE, CINAHL, OVID, ScienceDirect, Cochrane Library and PEDro. All randomized controlled trials (RCTs) of sensory organization training in adult patients with stroke aged 18 years or more at any stage post-stroke were retrieved. The methodological quality of studies was assessed, using the assessing risk of bias adapted from van Tulder scale and recommended by the Cochrane Handbook of Review of Interventions. A qualitative analysis was performed to assess the methodological quality scores using the GRADE approach recommend by the Cochrane Back Review Group. The results showed that three RCTs studies met the inclusion criteria which represented 104 participants from a wide range of time since stroke with a range approximating the chronic stage of stroke. There was moderate methodological quality evidence suggesting that balance rehabilitation program with additional sensory organization training had no adverse effect and might be beneficial on improving sensory organization and quality of life in persons with stroke. The additional sensory organization training did not lead to better improvement in limit of stability and functional activities than the conventional balance training. Thus, it could be concluded that additional sensory organization training is effective for improving short-term sensory organization and quality of life in stroke patients.

Keywords: *Balance, Stroke, Rehabilitation, Sensorimotor integration*

1. Introduction

Balance ability is an important component toward attaining autonomy in performing daily activities (Tyson et al., 2006; van de Port et al., 2006). Impairment of balance performance is one of the main problems commonly found in patients with stroke. This impairment occurs from several underlying causes, and can be targeted at the motor and sensory systems as well as sensorimotor integration and interpretation. Motor disorders such as muscle paresis or spasticity (Shumway-Cook & Horak, 2010) are one of the distinctive characteristics of subjects following stroke that can lead to poor postural control. Most stroke patients show decreased ankle proprioception and somatosensation at the feet (Lubetzky-vilnai & Kartin, 2010) and furthermore they have difficulties with multiple sensorimotor processes that require the central processing of vestibular, visual and somatosensory information to activate the musculoskeletal system for postural control (Hammer et al., 2008). The ability to choose and rely on the appropriate sensory input for each situation is called sensory reweighting (Horak, 2006). It is evidenced that the persons with stroke have impaired sensory reweighting such that they demonstrated more postural sway in the conditions of altered somatosensory information (Di Fabio & Badke, 1991) such as walking on uneven surface and walking in the dark. Measurement of sensory organization demonstrated that patients with stroke were mostly unstable in conditions of visual deprivation or inaccurate visual inputs, indicating the excessive reliance on visual input even when it provides inaccurate information (Bonan et al., 2004a). Balance rehabilitation in stroke is very crucial as a rapid and optimal balance improvement enables patients with stroke to reach their social independency (Geurts et al., 2005). At present, there are several types of balance training methods, including muscle strengthening (Orr et al., 2008), gait-oriented training (van de Port et al., 2007; Moseley et al., 2003) and standing balance training on force platform. However, current systematic review literature could not demonstrate significant balance improvement in patients with stroke from the above balance training methods (Lubetzky-vilnai & Kartin, 2010). This could be due to the fact that these balances training programs were not specific to individual's problem and they focused mainly at the motor output component, such as an ability to control balance while performing functional activity, with little emphasis on the sensorimotor integration or sensory reweighting. As sensory reweighting impairments is also affected in patients with stroke and such impairments could increase fall risks when navigating in the daily environment, it is vastly important to include the sensory organization training in the balance training program. The sensory organization training includes treatment strategies that require the patient to maintain balance during progressively more difficult static and dynamic movement tasks, while the clinician systematically varies the availability and accuracy of one or more senses for orientation, such as using uneven surface or performing balance task with eye closed (Shumway-Cook & Horak, 1989; 1990). Nevertheless, there is no systematic review that examines the effect of sensory organization training on improving balance performance in patients with stroke.

2. Objectives

To evaluate the effectiveness of sensory organization training on improving balance performance in patients with stroke by comparing this training program with conventional balance training program or no training.

3. Materials and Method

3.1 Inclusion criteria for considering studies

3.1.1 Types of studies

Published and unpublished reports of completed randomized control trials

3.1.2 Type of participants

Adult patients following stroke aged 18 years or more at any stage along the continuum of post-stroke recovery.

3.1.3 Types of intervention

The control group received conventional balance training that performed all exercises under normal conditions (i.e., free vision and on firm surface) or no treatment. The experimental group received the same exercises with additional sensory organization training or sensory organization training alone. The sensory organization training includes treatment strategies that require the patient to maintain balance during progressively more difficult static and dynamic movement tasks, while the clinician systematically varies the availability and accuracy of one or more senses for orientation (Shumway-Cook & Horak, 1989; 1990).

3.1.4 Language

All articles that published in English language were selected

3.1.5 Type of outcome measures

Trials that had at least one of the two primary outcome measures; postural sway or functional balance scores were included. Postural sway was assessed in the standing position during altered sensory condition such as Sensory Organization Test (SOT) score, center of pressure (CoP) displacement and the subjective sway from using the Modified Clinical Test of Sensory Interaction on Balance (mCTSIB). Functional balance scores were obtained from Berg Balance Scale (BBS), Time Up and Go test (TUG), 10-m walking test. The timing of outcome measurements were divided into two categories: 1) short-term: when the outcome assessment was taken at the end of the intervention period; and 2) long-tern: when the outcome assessment was taken at more than 1 month later after the intervention.

3.2 Search strategy for identification of studies

Seven computerized database (detail in figure 1) were searched during July and August 2011. Two groups of key words were used: Subjects keywords (stroke, hemiplegia, hemiparesis, hemiparetic, cerebral vascular accident) and intervention keywords consisting of three components; balance, training and altered sensory input. Hand search was used for reference lists in review articles guidelines, and retrieved trials.

3.3 Selection of trials

One reviewer conducted the electronic searches and hand search for selected the studies that met inclusion criteria. The results were merged using Endnote X2 and duplicates were manually removed.

3.4 Data extraction and quality assessment

3.4.1 Data extraction

The reviewer collectively screened all titles for relevant studies. Abstracts were chosen from the titles. In the review of abstracts, duplicates and those that were not met the inclusion criteria were rejected. Full text articles were first reviewed individually and then collectively. Reviewer was not blinded for authors, institutes or journals. Data extracted from the studies include sample size and drop outs, mean age of patient and timed since stroke, type, intensity and duration of intervention, type of outcome measures used and results or the author's conclusions about the effectiveness of the intervention.

3.4.2 Methodological quality

For the selected articles, two reviewers (BC, SN), assessed the methodological quality of each studies. In the case of disagreement, reviewers tried to reach consensus, and if necessary, a third reviewer helped to solve disagreements. The quality was assessed based on 12 validity characteristics for assessing risk of bias (Table 3), and one point was assigned for the presence of each component (Furlan et al., 2009). These instructions are adapted from van Tulder (Van Tulderet et al., 2003) and Boutron, et al. (Boutron et al., 2005) and the Cochrane Handbook of Review of Interventions (Higgins et al., 2008). Furlan, et al. recommended that when the study was scored at six of the 12 CBRG criteria and the study has no serious flaws (e.g., 80% drop-out rate in 1 group), this indicates low risk of bias (Furlan et al., 2009). The studies with serious flaws or scored fewer than six of criteria are indicated as high risk of bias. Authors graded the included RCTs independently, and consensus was reached following discussion.

3.5 Data analysis

Due to the small number of included studies, statistical pooling was not possible. Therefore, the methodological quality scores were selected to determine the best quality study. This analysis method was recommended by the Cochrane Back Review Group (CBRG) Editor Board from Cochrane Handbook of Systematic Review of interventions (Higgins et al., 2008). The quality of evidence on specific outcome is based on five domains consisting of limitations of study design, inconsistency, indirection (inability to conventionalize), imprecision (insufficient or imprecise data) of results and publication bias across all studies that measure that particular outcome (Furlan et al., 2009). The overall quality of evidence for each outcome was the result of the combination of assessment in all domains. The GRADE Working Group recommends four levels of evidence as the criteria in Table 1.

Table 1 The GRADE Approach for Overall Quality of Evidence for Each Outcome

Level	Criteria
High quality evidence	At least 75% of the RCTs with no limitation of study design have consistent finding, direct and precise data and no known or suspected publication biases.
Moderate quality evidence	1 of the domain is not met.
Low quality evidence	2 of the domains are not met.
Very low quality evidence	3 of the domains are not met.
No evidence	No RCTs were identified that addressed this outcome.

4. Result and Discussion

4.1 Study selection

The initial search resulted in 57 articles from seven databases (Figure 1). No additional study was found from hand searching. After the selection based on titles and abstract, 11 potentially relevant abstracts were found and thirty two articles were excluded due to irrelevant and 14 articles were repeated studies found on more than one database. Therefore, 11 full-text were obtained and critically appraised of which one was duplicated (full-text in different title) (Bonan etal., 2002), five studies did not have sensory integration in their interventions (Cheng et al., 2004; Conforto et al., 2010; Hillier& Dunsford, 2006; Lynch et al., 2007; Schabrun et al., 2009) and two studies were non- RCTs, (before and after study (Smania at al., 2008) and case report (Hakim, et al., 2011). Finally, three RCTs (Bayouk et al., 2006; Bonan et al., 2004b; Yelnik etal., 2008) were found to meet all selection criteria and were included in the present review.

4.2 Characteristic of studies

4.2.1 Participants

Three RCTs studies evaluated participants from a wide range of time since stroke with a range approximating the chronic stage of stroke. These studies included a total of 104 participants, of whom 51 were assigned to an experiment group. A further 53 subjects acted as controls. Their average aged between 49.5 and 68.4 years. Average timed since stroke ranged from 214.2 days to 7.1 years. Detail of stroke type in 55 subjects were absent, therefore, 49 subjects had suffered an ischemic stroke. Lesion location was divided between left hemisphere (N=41) and right hemisphere (N=43) and some details in 20 subjects were absent. No adverse effects were reported from any sensory integration training interventions. Further characteristics of included studies are listed in Table 2.

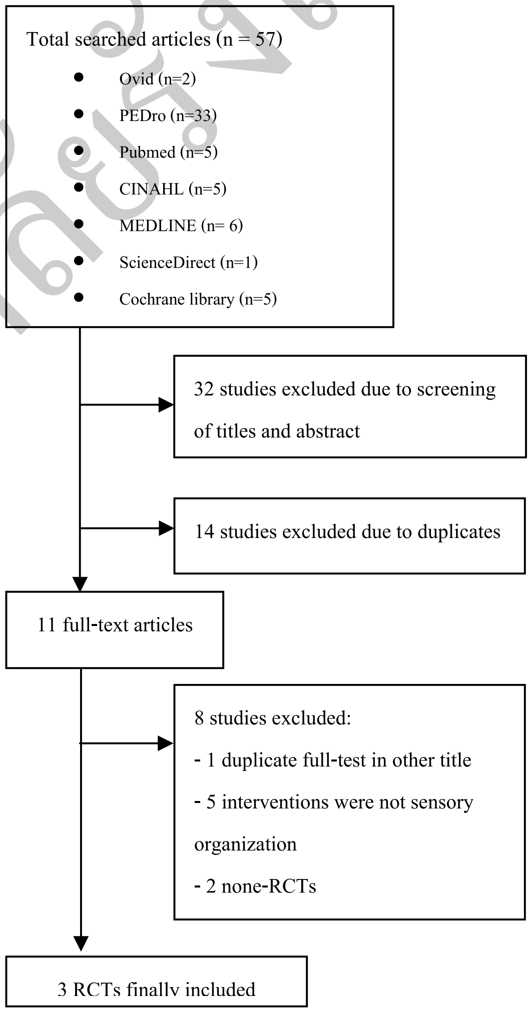

Figure 1 Flowchart of Included Studies

4.2.2 Quality assessment

All RCTs studies were categorized as low risk of bias by scoring seven to 10 of the 12 CBRG criteria with no serious flaws. The criteria which the included studies did not meet were not being random assigned, blinded intervention and blinded assessment (details in Table 3).

4.2.3 Intervention

4.2.3.1 Type of intervention

Three RCTs studies were conducted during the chronic phase of stroke. They examined the effects of balance training program with and without sensory organization training. Balance training programs in all studies were either functional balance training or training to control postural stability during functional tasks. In one study, the balance training program was task-oriented exercises that were designed for abnormally increased lateral sway during double-legged stance and sit to stance task (Leroux, 2002). The additional sensory organization consisted of visual deprivation in one study and altered sensory condition in two studies where performing functional balance under eye closed, visual deprived, on unstable or foam surface, and/or head tilting.

4.2.3.2 Intensity and duration

All RCTs intervention programs required 2-5 times per week for 1-hour training sessions over 4-8 weeks.

The total training sessions range from 16 (Bayouk et al., 2006) to 20 sessions (Bonan et al., 2004b; Yelnik et al., 2008). Two studies reported 100% adherence and Yelnik et al reported 4.1% attrition (1 lost to follow-up between day 30^{th} and day 90^{th} and 2 for unrelated health reason) (Yelnik etal., 2008).

Table 3 Criteria for Assessing Risk of Bias (Limitation of Design) and Quality Assessment Scores Design) and Quality Assessment Scores

Sources of risk of bias			
Criteria	Bonan	Boyouk	Yelnik
1. Method of randomization adequate?	Yes	Unsure	Yes
2. Treatment allocation concealed?	Yes	Unsure	Yes
3. Patient blinded?	No	No	No
4. Care provider blinded?	No	No	No
5. Outcome assessor?	No	No	Yes
6. Drop-out rate acceptable?	Yes	Yes	Yes
7. Participants random to group follow they were allocated?	Yes	Yes	Yes
8. Reports study free of selective outcome reporting?	Yes	Yes	Yes
9. Each had similar at baseline?	Yes	Yes	Yes
10. Co-interventions avoided?	Yes	Yes	Yes
11. Compliance acceptable?	Yes	Yes	Yes
12. Timing of the outcome assessment similar in all groups?	Yes	Yes	Yes
Total score	9/12	7/12	10/12

4.2.3.3 Measurement

The valid outcomes measure for assessing sensory organization is a Sensory Organization Test (SOT). There were one studies used this outcome measure (Bonan et al., 2004b). Outcome measurement tool in other RCTs were force platform. Boyouk et al used force platform for measuring center of pressure (CoP) displacement (postural sway) during double-legged stance under varied sensory conditions (Bayouk et al., 2006), while Yelnik et al. examined CoP displacement during lean forward, backward, left and right (limit of stability) (Yelnik etal., 2008). The most common outcomes for assessing functional balance was gait speed (by 10-m walking test (N=4) and TUG (case report)). One studies (Yelnik etal., 2008) selected BBS for assessing functional balance and two studies (Bonan et al., 2004b; Yelnik etal., 2008) examined the quality of life by using the Nottingham Health Profile (NHP).

4.2.3.4 Effect of sensory organization training

Two studies (Bayouk et al., 2006; Bonan et al., 2004b) showed significant improvement of SOT score at the end of training program. In the studies by Bonan et al and Boyouk et al (moderate quality), the author showed that those who received functional balance training or task oriented training alone or plus the sensory organization training did improve postural sway during altered sensory condition (Bayouk et al., 2006; Bonan et al., 2004b). Most significant improved condition was eye open on firm (SOT 1) and soft surface (SOT 4). Only study of Bonan et al showed moderate evidence that task oriented training plus sensory organization training is better than task oriented training alone in SOT 1, SOT 4 and tended to differ in SOT 5 (p=0.08) (Bonan et al., 2004b). In the studies of Yelnik et al (moderate quality) and Hakim et al, the author showed equal benefits of functional balance training alone and with sensory organization training when the outcome measure was BBS score. Similarly, high quality evidence reported equal effect when the outcome measure was gait speed (Yelnik etal., 2008). The study of Yelnik et al (moderate quality) reported better effect of functional balance training alone and with sensory organization training on improving quality of life (Yelnik etal., 2008). All studies did not report adverse effects that resulted from both functional balance training and sensory organization training.

5. Discussion

A small number of studies examined the effects of sensory organization training on improving balance performance in patients with stroke. The results of this systematic review are based on 3 RCTs with high and moderate methodological qualities (104 participants). The findings suggest that balance rehabilitation program with additional sensory organization training had no adverse effect and might be beneficial on improving sensory reweighting and quality of life in persons with stroke. Although this result is promising in term of improving the ability to reweigh multi-sensory inputs and decreased visual reliance for persons with stroke, further studies were required to increase the number of patients and improve the ability to generalize across a variety of patients with stroke.

When comparing to the conventional balance training, the balance training with additional sensory organization training, however, did not show better improvement in limit of stability and functional balance. The interpretation of this finding should be done with lots of consideration, as the selection of outcome measures may affect the outcome of the training. For example, BBS has significant floor effect at 14 days post stroke and large ceiling effect in high functioning such as community-dwelling stroke (Blum & Korner-Bitensky, 2008). Lubetzky-Vinai and Kartin (2010) also provided strong evidence that the BBS is very sensitive to change in the acute stage or in the chronic stage for individuals who started with a low BBS score (< 35). For the participants with a higher score, it is unclear whether little improvement was made or whether the test was not sufficiently sensitive to demonstrate change (Lubetzky-vilnai & Kartin, 2010). Most of participants in our systematic review are at the chronic stage of recovery, therefore, BBS may not be able to detect the actual effect of sensory organization training. Moreover, the BBS does not capture the extent to which an individual's visual reliance in maintaining balance; hence, it may not be appropriate to demonstrate a change resulted from multisensory training with visual deprivation (Hammer et al., 2008).

Despite the result of finding want a further confirmation of a benefit on functional balance but additional sensory organization training to conventional balance training can improved sensory reweight, decrease excessive reliance visual and no has adverse effect. Therefore, clinician must be consider to assess the sensory organization and add it into balance training program in stoke patients. These approach call problem-orientated approach which the systematic review of Hammer et al (Hammer et al., 2008). Furthermore, future research should focus on high-quality randomized controlled trials with high statistical power and consistent and reliable and valid outcome measures. Study should be comparison between sensory organization training alone with conventional balance training and with additional to conventional balance training

6. Conclusion

There is moderate-quality evidence that balance training with additional sensory organization training is more effective than conventional balance training program alone for improving short-term sensory organization and quality of life in stroke patients. However, functional balance, limit of stability and gait speed did not improve when adding sensory organization to conventional balance training program.

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8. References

Blum L, Korner-Bitensky N. (2008). " Usefulness of the Berg Balance Scale in stroke rehabilitation: a systematic review". Phys Ther. 88(5):59-66.

Bonan, I et al. (2002). "Effectiveness of a balance rehabilitation programme with visual cue deprivation after stroke: a randomized controlled trial". Clin Rehabil. 808-809.

Bonan IV, Colle FM, Guichard JP, Viacut E, Eisenfisz M, Tran Ba Huy P, Yelnik AP. (2004). "Reliance on visual information after stroke. Part I: Balance on dynamic posturography". Arch Phys Med Rehabil . 85(2): 268–73.

Bonan, I.V., et al. (2004). "Reliance on visual information after stroke. Part II: Effectiveness of a balance rehabilitation program with visual cue deprivation after stroke: a randomized controlled trial". Arch of Phys Med and Rehabil. 85: 274-8.

Boyouk, J.F., J.P. Boucher, and A. Leroux (2006) "Balance training following stroke: effects of task-oriented exercises with and without altered sensory input".In J of Rehabil Res. 29(1): 51-9.

Boutron I, Moher D, Tugwell P, et al. (2005). "A checklist to evaluate a report of a nonpharmacological trial (CLEAR NPT) was developed using consensus". J Clin Epidemiol.58: 1233-40.

Cheng, P., et al., (2004). "Effects of visual feedback rhythmic weight-shift training on hemiplegic stroke patients". Clin Rehabil. 18(7): 747-53.

Conforto, A.B., et al., (2010). "Effects of somatosensory stimulation on motor function after subacute stroke". Neurorehabilitation. 24(3): 263-72.

Di Fabio RP, Badke MB. (1991). "Stance duration under sensory conflict conditions in patients with hemiplegia". Arch Phys Med Rehabil. 72: 292-5.

Furlan AD, Pennick V, Bombardier C, Maurits van Tulder. (2009). "2009 Update method guideline for systematic review in the Cochrane Back Review Group". Spine. 34(18): 1929-41.

Geurts A, de Haart M, van Nes I, Duysens J. (2005). "A review of standing recovery from stroke". Gait& Posture. 22:267-81.

Hakim, R.M., et al., (20011). "A computerized dynamic posturography (CDP) program to reduce fall risk in a community dwelling older adult with chronic stroke: A case report". Physiother Theory Prac. early online: 1-9

Hammer A, Nilsagard Y, Wallquist. (2008). "Balance training in stroke patients-a systematic review of randomized, controlled trials". Adv in physiother.10: 163-72.

Higgins J, Green S, eds. (2008). Cochrane Handbook for Systematic Reviews of Interventions Version 5.0.0 [updated February 2008]. The Cochrane Collaboration.

Hillier, S. and A. Dunsford, (2006). "A pilot study of sensory retraining for the hemiparetic foot post-stroke". Journal Rehabil Res. 29(3): 237-42.

Horak FB. (2006). "Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? "Age Ageing. 35 Suppl 2: ii7-ii11.

Leroux A. (2002). "Improvement in balance and mobility after exercise training in elderly individuals with stroke". Arch Phys Med Rehabil. 83:1492.

Lubetzky-vilnai A, Kartin D. (2010). "The effect of balance training on performance in individuals post stroke: a systematic review". JNPT. 34:127–37.

Lynch, E.A., et al., (2007). "Sensory retraining of the lower limb after acute stroke: a randomized controlled pilot trial". Arch Phys Med Rehabil. 88(9): 1101-07.

Moseley AM, Stark A, Cameron ID, Pollock A. (2003). "Treadmill training and body weight support for walking after stroke". Cochrane Database Syst Rev 2003(3): CD002840.

Orr R, Raymond J, Fiatarone Singh M. (2008). "Efficacy of progressive resistance training on balance performance in older adults: a systematic review of randomized controlled trials". Sports Med. 38(4): 317-43.

Schabrun, S.M. and S. Hillier. (2009). " Evidence for the retraining of sensation after stroke: a systematic review [with consumer summary]". Clinical Rehabilitation. 23(1): 27-39.

Shumway-Cook A, Horak FB. (1989). "Vestibular rehabilitation: an exercise approach to maintaining symptoms of vestibular dysfunction". Semin Hearing. 10: 196-205.

Shumway-Cook A, Horak FB. (1990). "Rehabilitation strategies for patients with vestibular deficits". Neurol Clin. 8: 441-57.

Shumway-Cook A, Horak FB. (2010). Motor control: translation research to practice. 4th ed. Philadelphia: Lippincott Williams & Wilkins : 300-2.

Smania N, Picelli A, Gandolfi M, Fiaschi A, Tinazzi

M. (2008). "Rehabilitation of sensorimotor integration deficits in balance impairment of patients with stroke hemiparesis: a before/after pilot study". Neuro Sci. 29: 313-19.

Tyson SF, Hanley M, Chillala J, Selley A, Tallis RC. (2006). "Balance disability after stroke". Phys Ther. 86: 30-8.

Van de Port IG, Wood-Dauphinee S, Lindeman E, Kwakkel G. (2007). "Effects of exercise training programs on walking competency after stroke: a systematic review". Am J Phys Med Rehabil. 86(11): 935-51.

Van de Port IGL, Kwakkel G, Schepers VPM, Lindeman E. (2006). "Predicting mobility outcome one year after stroke: A prospective study". J Rehabil Med. 38: 218–23.

Van Tulder M, Furlan A, Bombardier C, et al. (2003). "Updated method guidelines for systematic reviews in the Cochrane collaboration back review group". Spine. 28: 1290-9.

Yelnik, A.P., et al., (2008). "Rehabilitation of balance after stroke with multisensorial training: a single-blind randomized controlled study". Neurorehabilitation & Neural Repair. 22(5): 468-76.

Table 2 Included Randomized Controlled Trials (RCTS) on Sensory Organization Training

Study	No. randomized /dropouts	Age (year)	Time after stroke	Intervention type	Intervention duration	Intervention intensity	Outcome	Results
Bonan et al. 2004	Exp 10/0 Con 10/0	Exp 49.5 ± 10 Con 49 ± 17	Exp 20.5 ± 25 months Con 20.5 ± 10 months	Functional balance training (supine to gait) in under vision deprivation vs. in under free vision	4 weeks	5sessions /week of 60 min	Postural sway: SOT Equilibrium Score (ES) Clinical balance: gait velocity, timed stair climbing, gait quality QOL: Nottingham Health Profile (NHP)	*Within group*: Sig. improve ES score in SOT5 and SOT6, gait velocity and gait quality in both group (P<0.05) *Between group*: Exp. Sig. improve in SOT1 and SOT4 than Con (P<0.05) and Exp. tended to be greater in SOT% than Con (P=0.08)
Boyouk et al. 2006	Exp 8/0 Con 8/0	Exp 64.4 ± 7.1 Con 62 ± 4.6	Exp 7.1 ± 12.5 years Con 5.7 ± 6.9 years	Task-oriented exercise target on balance, gait and coordination in under 4sensory condition EO on firm surface, EO on soft surface, EC on firm surface and EC on soft surface vs. in under normal condition (EO on firm surface)	8 weeks	2sessions /week of 60 min	Postural sway: CoP variability during 10s double legged stand and CoP total excursion during sit to stand from a chair under 4 sensory condition Clinical balance: 10-m walking test	*Within group*: Sig. improve CoP variability during 10 s double legged stand under condition EO on firm (ML direction) and soft surface (AP direction) in Exp (P<0.05) Sig. improve CoP total excursion during sit to stand under condition EO soft surface (AP direction) in both group Sig. improve walking speed in both group (P<0.05) *Between group*: All outcome had no sig. between group
Yelnik et al. 2008	Exp 33/2 Con 35/1	Exp 55.5 ± 11.6 Con 54.9 ± 11.8	Exp 217.2± 92.7 days Con 218.4± 93.4 days	Rehabilitation based on multisensory condition to maintain balance vs. NDT based treatment target on control of weight shifting and gait	4 weeks	5sessions /week of 60-70 min	Limit of stability: CoP displacement Clinical balance: BBS, % double –limb stance time, 10-m walking test, timed stair climbing, subjective perception of security during walking, number of fall since stroke FIM and QOL:NHP	*Within group*: BBS score, walking speed, % double-limb stance time, timed stair climbing and FIM sig. improve in both group (P<0.05) at end of program and 90 days follow-up and daily time walking in both group sig. improve only end of program *Between group:* Exp. Sig. improve in % double-limb stance time, FIM and QOL than Con (P<0.05) at end of program and 90 days follow-up and number fall sig. improve only end of program

Exp = experiment group; Con = control group; min = minute; SOT = sensory organization test; ES = equilibrium score; QOL = quality of life; NHP = Nottingham Health Profile; EO = eye open; EC eye close; CoP = center of pressure; ML= mediolateral; AP = anteroposterior; NDT = Neurodevepmental Treatment; BBS = Berg Balance Scale; FIM = Functional Independent Measurement. Significant findings were tested at p<0.05