Are unstable support surfaces superior to stable support surfaces during trunk rehabilitation after stroke? A systematic review

Are unstable support surfaces superior to stable support surfaces during trunk rehabilitation after stroke? A systematic review.

Objective: To investigate the effect of trunk rehabilitation using unstable support surfaces, compared to stable support surfaces, on static and dynamic balance after stroke

Materials and methods: A systematic review was conducted to identify relevant articles from the following databases: Medline (Pubmed), Web of Science, PEDro, REHAB+, Rehabdata, Science Direct, CIRRIE and Cochrane library. Studies were included when they involved adult stroke patients; were controlled clinical trials; assessed static and dynamic balance; and incorporated trunk exercises on stable or unstable support surfaces. Databases were systematically screened until April 2017. Risk of bias assessment was performed by means of the PEDro scale.

Results: Seven studies met the inclusion criteria, of which one had a low risk of bias, and six a high risk. In total, 184 stroke patients were evaluated. Unstable support surfaces used during therapy were physio balls, balance pads, air cushions, tilting boards and slings. Trunk training was provided either as additional therapy or without conventional therapy. All modalities, except for the sling, showed larger improvements compared to stable support surfaces on balance performance.

Conclusion: Trunk training on unstable support surfaces seemed to be superior to stable support surfaces in improving static and dynamic balance. However, more research is necessary, since the risk of bias of the included studies was high.

Keywords: cerebrovascular disorders, stroke, trunk, rehabilitation, balance, gait

Introduction

Although retraining of the trunk has been considered of value in stroke rehabilitation [1,2], it is still unclear which modalities are the most effective in improving static and dynamic balance. Literature has suggested that trunk training is a good rehabilitation strategy for retraining trunk performance, standing balance and gait after a stroke [3-6]. Trunk rehabilitation incorporates exercises which focus on trunk muscle strength, trunk selectivity and trunk coordination. Different exercises such as sitting training, which can include reaching activities and weight shifting exercises, and/or core stability training, which can consist of bridging exercises and crunches, can be included in a trunk training protocol. However, one should consider the interference of lower limb activity in some exercises. Additionally, they may be executed with or without electromechanical devices, and may be performed on stable or unstable support surfaces. However, the heterogeneity of the exercise protocols used in previous research makes it difficult to give recommendations for clinical practice.

The use of unstable support surfaces in trunk rehabilitation has become more popular, since unstable support surfaces result in increased muscular activity during the execution trunk exercises [7-9]. Moreover, these type of exercises improve muscle strength, endurance, trunk flexibility, dynamic balance, and proprioception [10,11]. Therefore, changing the support surface during trunk rehabilitation might be a good strategy in enhancing static and dynamic balance. On the other hand, the benefits of unstable support surfaces might not outweigh the possible disadvantages such as increased muscle fatigue and fear of falling. Therefore, it is not yet clear whether exercises performed on unstable support surfaces are superior to stable support surfaces in improving balance during trunk rehabilitation.

Consequently, the aim of this review is to evaluate the effect of unstable support surfaces, compared to stable ones during trunk rehabilitation on static and dynamic balance, in order to see which support surfaces should be recommended for trunk rehabilitation.

Materials and Methods:

Search Strategy

This review was conducted according to the Preferred Reporting Items for Systematic Review and Meta-Analysis Statement (PRISMA) and registered in the PROSPERO database (no. CRD42016042950) [12]. Electronic databases Medline (Pubmed), Web of Science, PEDro, REHAB+, Science Direct, Rehabdata and CIRRIE by NARIC, and Cochrane library were systematically screened. Two reviewers (TVC, WS) independently screened for eligibility based on title and abstract. Studies retained for full-text evaluation were assessed to ensure that all eligibility criteria were met. Reference lists were screened for additional studies which were not yet identified during the systematic search. Afterwards evaluations were pooled, a consensus was reached by a third reviewer (ST) when discrepancies occurred between the first two researchers. The search strategy is made available in Appendix A. The final literature search was performed in April 2017.

Study selection

The studies had to meet the following inclusion criteria: 1) randomized controlled studies or controlled clinical trials; 2) adult participants (age 18 or older) with primary diagnosis of ischaemic and/or haemorrhagic stroke; 3) studies comparing a specific trunk training exercise protocol on stable versus unstable support surfaces; 4) outcome measures based on static and dynamic sitting and standing balance, and gait; and 5) studies written in English, Dutch, German or French.

Studies were excluded when interventions were not adequately specified or when training involved exercises while standing and/or walking. Subsequently, trunk training protocols using additional electromechanical devices were excluded. No limitations were applied regarding time after stroke onset, length of intervention, and follow-up assessment.

Static and dynamic balance were considered as primary outcome measures and were categorized into three major subdivisions:

- Sitting balance, static and dynamic, measured by the distance reached, the performance of selective and functional movements, or the analysis of the variability in centre of pressure while sitting.
- Standing balance, static and dynamic, measured by centre of pressure displacements or clinical tests, assessing the ability to stand still during internal or external perturbations.

- Gait measured by assessing the distance, the time taken to execute a certain gait task or the quality of walking such as Timed Up and Go test or the Brunel Balance Assessment Stepping subscale.

Data extraction

The following data were extracted by two independent researchers (TVC, WS) and summarized in the data extraction table (Table 1): information concerning the first author, the year of publication, the number and characteristics of the participants, the outcome measures, the interventions, the results and the conclusions. Disagreement was resolved by a third researchers (ST).

Risk of bias

Risk of bias was assessed using the PEDro scale for quality assessment of randomized controlled trials [13]. Studies with a score of at least six were considered having a moderate to low risk of bias [14]. This assessment tool rates eleven aspects of methodological quality of RCT's as being either absent or present. The first item 'eligibility criteria' was not scored. In addition, the PEDro scale has been shown to be reliable and valid (ICC= 0.68 95%CI: 0.57-0.76; r= 0.31 to 0.69) [13,15]. Two independent researchers assessed the risk of bias (TVC, WS). A consensus was reached by a third reviewer (ST) when discrepancies occurred in the evaluations of the first two researchers. At last, the level of evidence of each study was determined based on the GRADE system for evaluating the quality of evidence [16].

Data Synthesis and Analysis

After reviewing the results of the selected studies, it was decided that no meta-analysis could be performed since the outcome measures and treatment protocols varied substantially. Statistical heterogeneity, performed by I^2 test, was calculated to assess the level of heterogeneity. The high degree of variation was a result of differences in outcome measures, intervention modalities and time post stroke. Cochrane guidelines were used to interpret the heterogeneity: 0-40% might not be important; 30-60% may represent moderate heterogeneity; 50-90% may represent substantial heterogeneity; 75-100% considerable heterogeneity [16]. However, to invigorate the qualitative interpretation of the results, several forest plots were provided. Outcome measures which showed a considerable amount of heterogeneity ($I^2 \geq 75\%$), were not further analysed with forest plots. A partial meta-analysis could be performed if similar outcome measure were used in at least two studies and if a complete dataset of the two studies was present. A complete dataset consisted of between-group differences, mean changes (MC), and standard deviations (SD). Authors were contacted concerning missing data. If no data was provided, no information was received from the contacted authors. In the case of missing data from a third study, SD were borrowed from the trials that reported them. This method has been proven to be reliable for performing meta-analyses [16,17]. Effect sizes were estimated and presented on pooled forest plots for sitting balance and gait. Confidence intervals were set at 95%. Additionally, the partial meta-analysis was performed by the Review Manager 5.3 software.

Results

Study selection

The search strategy resulted in 967 eligible studies obtained from electronic databases. After deduplication, 735 studies remained, of which 97 were identified as potentially relevant and were screened on full text. Manual screening of reference lists revealed two additional studies, which were included for further screening. In total, seven studies were included in this review [18-24].

Figure 1. Flow Chart

[Insert Figure 1. Flow Chart]

Risk of bias

Based on the PEDro scale for quality assessment, six studies had a high risk of bias and only one a low risk (Table 2). Due to methodological limitations regarding treatment protocol, the highest score possible was an eight out of ten; blinding of patients and therapist was not achieved in any of the studies. This is the case for the majority of rehabilitation studies, it is almost impossible to blind therapist and patients during rehabilitation. The median score was four out of ten. At last, all selected studies were randomized controlled trials, of which none derived their data from double-blinded experiments and were therefore all classified as having a level of evidence B.

Table 2. Risk of bias assessment

[Insert Table 2. Risk of bias assessment]

Study characteristics

Study characteristics are shown in table 1. In total 184 people suffering from stroke, with an average age of 58.44 years, received the following variations in trunk training. Five studies examined the effect of additional trunk training programs on unstable support surfaces compared to stable ones [18,19,21,23,24]. Two out of the seven studies did not mention whether the patients received conventional therapy [20,22]. The unstable support surfaces used in the studies were a physio ball [18,24], an air cushion [19], a sling [22,23], a balance pad [20] and a tilting board [21]. The majority of exercises consisted of core stability exercises such as bridging, dead bug position, upper and lower trunk flexion, extension and rotation [18,21-24]. The other two studies implemented a sitting training protocol consisting of weight-shift exercises[19,20]. Six studies investigated the effect of trunk training on standing balance [18,19,21-24], four on siting balance [18-20,24], and three on gait performance [20,23,24]. The Trunk Impairment Scale and the sitting subscale of the Motor Assessment Scale were used to examine sitting balance and trunk performance. The Berg Balance Scale, centre of gravity displacements, the standing subscale of the Brunel Balance Assessment, the subscale sit-to-stand of the Motor Assessment Scale, and the Frailty and Injuries: Cooperative Studies of Intervention Techniques Scale were used to assess standing balance. The 10-Meter Walking Test, Time Up and Go test, and the stepping subscale of the Brunel Balance Assessment were used to assess gait performance. The amount of therapy varied from a total of 5 hours to 30 hours between studies. The control group and experimental group received the same amount of therapy. In addition, both chronic and sub-acute patients were included in the studies. Time post stroke varied from days to months after stroke diagnosis. However, in the majority of studies the patient population were chronic stroke survivors, almost one year after stroke diagnosis.

Table 1. Overview of study characteristics and results of included trials

Insert [Table 1. Overview of study characteristics and results of included trials]

Synthesis of results

Sitting balance

Four studies compared the effect of trunk training executed on stable and unstable support surfaces on sitting balance and trunk performance [18-20,24]. The total score of the Trunk Impairment Scale, the dynamic, the coordination and the sitting subscale of the Trunk Impairment Scale and the Motor Assessment Scale showed significantly larger improvements in the unstable therapy group compared to the stable one [18-20,24]. Moreover, the mean change scores of the total Trunk Impairment Scale ranged from 3.70 to 7.93 points for the experimental group and 1.80 to 4.87 points for the control group respectively [18,20,24]. In the two studies assessing the subscales of the Trunk Impairment Scale, it was notable that the changes on the dynamic subscale of the Trunk Impairment Scale were larger than those on the coordination subscale [20,24]. Only the static subscale of the Trunk Impairment Scale was not able to demonstrate significant differences between both groups [20,24]. Subsequently, the type of support surface that resulted in larger improvements were physio balls, air cushions, and balance pads. Karthikbabu *et al* [24] showed the largest mean change of the total Trunk Impairment Scale (MC: 7.93 $\pm$ 1.28) on exercises performed on a physio ball compared to the balance pad (MC: 4.83 ± 2.17) [20,24]. The lowest mean change (MC: 3.7) was reported by a less qualitative study [18] and no detailed statistical data was reported by Ibrahimi *et al* [19] who compared plinth exercises to air cushions [19].

In summary, all studies suggested that exercises performed on unstable support surfaces were superior in increasing sitting balance compared to stable support surfaces. The overall effect size was Z = 5.68 ($p<0.00001$), favouring physio balls, balance pads, and air cushions (Figure 2). Yet, the level of heterogeneity in the studies was substantial ($I^2 = 63\%$, p=0.07, df = 2, $Chi^2 = 5.45$).

Standing balance

Six studies compared the effect of trunk training executed on stable and unstable support surfaces on static and dynamic standing balance [18,19,21-24]. Two studies using a sling did not find any significant differences between the experimental and control group when assessed with the Berg Balance Scale, sway area and sway length of the centre of gravity, and the Frailty and Injuries: Cooperative Studies of Intervention Techniques Scale [22,23]. In addition, physio balls failed to reach superior effects on measures of the Brunel Balance Assessment standing subscale, centre of gravity sway path and sway average speed [18,24].

On the other hand, significant differences were found on the total Berg Balance Assessment and centre of gravity sway area when physio balls were used [18,24]. The last two studies found significant larger improvements on both the Berg Balance Scale and the Motor Assessment subscale sit to stand for the exercises executed on an air cushion and tilting board [19,21].

In summary, no consensus has been reached regarding the superiority of unstable support surfaces on standing balance. Clinical outcome measures had an overall effects size of Z = 0.39 (p = .69). Biomechanical data could not be examined due to a significant amount of missing data. However, a great amount inconsistencies were observed in this clinical outcome measures (I^2 = 91%, p<0.001, df = 2, Chi^2 = 22.71). There is a tendency towards larger improvements during exercises performed on unstable support surfaces since only studies using a sling did not found any significant differences. Moreover, exercises performed on a physio ball, tilting board, and air cushion did show to be superior in the majority of assessed outcome measures than stable support surfaces.

Gait

Three studies investigated the effect of trunk training executed on stable and unstable support surfaces on gait performance [20,23,24]. Results showed that the 10-Minute Walking Test and the Brunel Balance Assessment stepping subscale showed larger improvements in the unstable therapy group compared to stable group [20,24]. The experimental group needed 5.4 $\pm$ 3.5 seconds less to walk 10 meters compared to the control group who walked 1.6 $\pm$ 2.6 seconds faster after trunk training [20]. In addition, the Brunel Balance Assessment mean change of the stepping subscale was only 2.8 $\pm$ 1.15 points for the control group compared to a mean change of 4.67 $\pm$ 1.29 points for the experimental group [24]. Yet, the Timed Up and Go test did not significantly differ between groups when a sling was used [23].

In summary, two studies concluded that unstable support surfaces resulted in larger improvements compared to stable support surfaces. One study who did not find any significant differences used a sling for the execution of the exercises. Balance pads and physio balls seemed to be superior. An overall effect size of Z = 4.40 (p<0.0001) was observed, showing no inconsistencies in results (I^2 = 0%, p = 0.63, df = 1, Chi^2 = 0.24) (Figure 3).

Figure 2. Forest plot Sitting Balance

Insert [Figure 2. Forest plot Sitting Balance]

Figure 3. Forest plot Gait Performance

Insert [Figure 3. Forest plot Gait Performance]

Discussion

The aim of this review was to investigate the effect of unstable support surfaces, compared to stable ones, during trunk rehabilitation on static and dynamic balance. Despite the fact that previous studies suggested that trunk training exercises improved trunk performance and dynamic sitting balance after stroke, it is still unclear which modalities should be used in enhancing trunk performance, standing balance and gait. Since trunk exercises executed on unstable support surfaces result in increased muscle activity compared to stable support surfaces [7], changing the support surface during trunk rehabilitation might be a good strategy in enhancing static and dynamic balance.

Results from this review showed a fair evidence to support the recommendation that trunk training executed on unstable support is superior to stable support surfaces. The level of evidence of the included studies was moderate, since none of the studies derived their data from double-blinded experiments. This methodological limitation is common in rehabilitation studies since it is extremely hard to blind therapist and patients. With the exception of sling exercise therapy, trunk exercises performed on unstable support surfaces had a tendency to result into larger improvements on static and dynamic balance. Although recommendations for the importance of trunk rehabilitation on unstable surfaces can be given concerning sitting balance and gait, no consensus has yet been reached regarding standing balance. However, results should be interpreted with caution since six studies had a high risk of bias and the heterogeneity of the included studies was high. The median PEDro score of the included studies was four out of ten. Some important quality components such as concealed allocation, blind assessors, adequate follow-up and an intention-to-threat analysis were absent in these studies. Only one study had a low risk of bias and had a PEDro score of eight. Although the latter clearly stated that unstable support surfaces are superior to stable ones, the high risk of bias of the remaining studies necessitates further research.

Support surfaces such as a physio ball, balance pad, tilting board and air cushion tended to be effective in enhancing balance performance. On the other hand, sling exercise therapy did not reach superior effects on static and dynamic balance in stroke survivors. Although Chen *et al* [25] concluded sling exercise therapy was superior on measures of balance when compared to conventional therapy, this review suggests that it is not superior to an identical trunk rehabilitation protocol executed on stable support surfaces. Previous studies on low back pain patients showed similar results, they reported that sling exercise therapy was not more effective than general exercise in reducing pain and disability in low back pain patients [26].

Several studies reported that unstable surfaces induce increased activation of the trunk musculature due to a constant muscle response, which is required to withstand the postural perturbations provided by the unstable support [27-30]. Marshal *et al* [28] suggested that muscle activity increased when the centre of mass is further away from the unstable support surface and when the contact area is reduced. Hence, simple reaching exercises and weight-shift exercises which displaces the centre of mass are already able to increase muscle activity. Therefore, patients do not need to execute difficult and advanced exercises to benefit from trunk training on unstable support surfaces. Moreover, the relative activity between different muscles groups can be altered on unstable support surfaces [28,31]. The relative activity of muscles is of great importance during feedforward anticipation of postural control. An anticipatory postural adjustment of the trunk is initiated before a distal movement, to decrease disturbances and to preserve postural control during external or internal perturbations [32]. To diminish the disturbances, the activation of a local stabiliser proceeds the activation of the primary mover. Studies have shown that stroke survivors have impaired anticipatory postural adjustments which are expressed by delayed onset times and reduced synchronization between muscle pairs [33,34]. Therefore, trunk rehabilitation on unstable support surfaces might not only increase muscle activity but also improve anticipatory postural adjustments of the trunk and synchronization of local and global stabilizers. Studies including low back pain patients have already demonstrated a positive change in anticipatory postural adjustments after receiving rehabilitation on unstable support surfaces [35]. However, improvements in standing balance and gait might not solely be attributed to the changes in trunk muscular activity since lower limb muscles are always active during forward bending exercises [36]. Although unstable support surfaces require greater activation of the lower limb muscles compared to stable support surfaces, they cannot be the sole reason for these improvements. Since great improvements were also seen in sitting balance which only assesses trunk function.

Although the majority of studies suggest that unstable support surfaces are superior to stable ones, several studies on healthy subjects provided evidence that not all exercises were superior and that some exercises only increase specific muscle groups [7,29]. For example, Lehman *et al* [7] concluded that prone bridging resulted in increased activity of the rectus abdominus and external oblique muscles. The internal oblique and erector spinae muscles were not influenced by prone bridging on a physio ball [7]. On the other hand, Kong *et al* [37] reported a high increase in internal and external oblique muscles, rectus abdominus and erector spinae muscles during prone bridging. Additionally, sitting on unstable surfaces without executing trunk exercises did not result in an increased activity of the superficial trunk musculature [38]. Further research is necessary to make clinical recommendations of which exercises are the most beneficial on unstable support surfaces to increase trunk muscular activity.

There are a few limitations of this review that should be acknowledged. During the systematic literature search, only studies written in Dutch, English, German, or French were included. It is therefore possible relevant studies and important information was missed during the search process. In addition, both chronic and sub-acute patients were included in the studies. Time post stroke varied from days to months after stroke diagnosis. However, in the majority of studies the patient population were chronic stroke survivors, almost one year after stroke diagnosis. Yet, the largest improvements were seen in the study of Karthikbabu *et al* [24]who included sub-acute stroke patients compared to remaining studies who included chronic patients. Therefore, time post stroke might be a crucial factor in the amount of improvements seen. Implementing unstable support early in rehabilitation might be more beneficial.

In conclusion, there is a fair evidence that trunk training on unstable support surfaces might be a more effective method to enhance sitting balance and gait than trunk training on stable support surfaces. Although a positive trend was reported towards improving standing balance, no consensus has been reached. Unstable support surfaces such as physio balls, balance pads, air cushions, and unstable boards tended to be superior to stable support surfaces. Therefore, we recommend physiotherapists to integrate trunk exercises on unstable support surfaces into conventional therapy. Moreover, it might be more beneficial to incorporate these exercises as early as possible into rehabilitation. However, the high risk of bias of the included studies necessitates further study.

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Declaration of Interest Statement

The authors report no conflicts of interest.

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Appendix

A. Search Strategy

PubMed	("stroke"[All Fields] OR "cerebrovascular disorders"[All Fields] OR “hemiplegia” [All Fields] OR "stroke"[MeSH] OR "cerebrovascular disorders"[MeSH] OR “hemiplegia” [MeSH]) AND ("trunk exercises"[All Fields] OR "truncal exercises"[All Fields] OR "trunk performance"[All Fields] OR "truncal function"[All Fields] OR "trunk function"[All Fields] OR “sitting”[All Fields] OR "reaching"[All Fields] OR "core stability"[All Fields]) AND ("gait"[All Fields] OR "lower limb function"[All Fields] OR "ambulation"[All Fields] OR "locomotion"[All Fields] OR "walking"[All Fields] OR "balance"[All Fields] OR "mobility"[All Fields] OR "weight shift"[All Fields] OR "stability"[All Fields])
Web of Science	(“stroke” OR “hemiplegia” OR “cerebrovascular disorder”) AND (“trunk exercises” OR “truncal exercises” OR “trunk performance” OR “truncal performance” OR “truncal function” OR “trunk function” OR “sitting training” OR “reaching” OR “Core stability”) AND (“gait” OR “lower limb function” OR “ambulation” OR “locomotion” OR “walking” OR “balance” OR “mobility” OR “weight shift” OR “stability”)
PEDro Cochrane Library CIRRIE REHABDATA REHAB+ Science Direct	“stroke” AND “trunk”

Tables

Table 2. Risk of Bias Assessment

Study	PEDro score	1	2	3	4	5	6	7	8	9	10
Bae et al (2013)	4	yes	no	yes	no	no	no	no	no	yes	yes
Ibrahimi (2010)	4	yes	no	yes	no	no	no	no	no	yes	yes
Jung et al (2016)	5	yes	no	yes	no	no	yes	no	no	yes	yes
Karthikbabu et al (2011)	8	yes	yes	yes	no	no	yes	yes	yes	yes	yes
Lee et al (2014)	4	yes	no	yes	no	no	no	no	no	yes	yes
Park et al (2014)	4	yes	no	yes	no	no	no	no	no	yes	yes
Yoo et al (2014)	4	yes	no	yes	no	no	no	no	no	yes	yes

1. Random allocation; 2. Concealed allocation; 3. Baseline comparability; 4. Blind subjects; 5. Blind therapists; 6. Blind assessors; 7. Adequate follow-up; 8. Intention-to-threat analysis; 9. Between groups comparison; 10. Point estimates and variability

Table 1. Overview of study characteristics and results of included trials

Study	Participants			Interventions		Outcome Measures	Results		Conclusion
	N	*Age (yrs)*	*MTPS*	*Experimental (unstable)*	*Control (stable)*		*MC experimental*	*MC Control*	
Bae et al (2013)	16	E: 52.4 ± 7.6 C: 53.4 ± 5.8	E: 18.1 ± 4.2m C: 17.9 ± 4.3m	CT + TT (ball) 30h, 12 weeks, 5x/week, 30'	CT + TT	**Sitting balance** TIS **Standing balance** Sway path COG Sway area COG Sway average speed COG	TIStot: 3.7 (no SD) Sway path: -45.5 mm (no SD) Sway area: -40 mm² (no SD) Sway average speed: -26.7 mm/s (no SD)	TIStot: 1.8 (no SD) Sway path: -52 mm (no SD) Sway area: -46.5 mm² (no SD) Sway average speed: -29.7 mm/s (no SD)	TIStot: EG p<0.05; CG p<0.01 Sway path: EG p<0.05 ; CG p<0.05 Sway area: EG p<0.05 ; CG NS Sway average speed: EG: NS ; CG: NS
Ibrahimi et al (2010)	30	/	/	CT + TT (air cushion) 5h, 2 weeks, 5x/week, 30'	CT + TT	**Sitting balance** MAS sitting **Standing balance** BBS MAS sit to stand	No data	No data	MAS sitting: p<0.0001 BBS: p<0.001 MAS sit to stand: p<0.0001
Jung et al (2016)	24	E: 58.9 ± 11 C: 60.7 ± 7.8	E: 8.0 ± 3.2m C: 8.4 ± 2.4m	TT (balance pad) 10h, 4 weeks, 5x/week, 30'	TT	**Sitting balance** TIS **Gait** 10MWT	TIStot: 4.83 ± 2.17 TISstat: 0.58 ± 0.79 TISdyn: 2.42 ± 1.24 TIScoo: 1.83 ± 1.03 10MWT: 5.4 s ± 3.5	TIStot: 2.42 ± 2.35 TISstat: 0.67 ± 1.07 TISdyn: 0.92 ± 1.56 TIScoo: 0.83 ± 1.19 10MWT: 1.6 s ± 2.6	TIStot: p<0.05 TISstat: NS TISdyn: p<0.05 TIScoo: p<0.05 10MWT: p<0.05
Karthikbabu et al (2011)	30	E: 59.8 ± 10.5 C: 55 ± 6.5	E: 11.8 ± 8.1d C: 12.1 ± 7.5d	CT + TT (ball) 12h, 3 weeks, 4x/week, 1h	CT + TT	**Sitting balance** TIS **Standing balance** BBA standing **Gait** BBA stepping	TIStot: 7.93 ± 1.28 TISstat: 1.27 ± 0.59 TISdyn: 4.07 ± 1.34 TIScoo: 2.53 ± 0.52 BBA standing: 1.53 ± 1.06 BBA stepping: 4.67 ± 1.29	TIStot: 4.87 ± 1.25 TISstat: 1.2 ± 0.68 TISdyn: 2.6 ± 0.98 TIScoo: 1.2 ± 0.41 BBA standing: 1.6 ± 0.74 BBA stepping: 2.8 ± 1.15	TIStot: p=0.0001: TISstat: NS TISdyn: p=0.002 TIScoo: p=0.0001 BBA standing NS BBA Stepping: p=0.0001
Lee et al (2014)	20	E: 63.40 ± 4.94 C: 62.50 ± 8.48	/	CT + TT (sling) 6h, 4 weeks, 3x/week, 30'	CT + TT	**Standing balance** BBS FICSIT-4 Sway length COG Sway speed COG **Gait** TUG	BBS: 1.00 (no SD) FICSIT-4: 1.00 (no SD) Sway length: -16.2 mm (no SD) Sway speed: -0.9 mm/s (no SD) TUG: -1.18 s (no SD)	BBS: 2.6 (no SD) FICSIT-4: 2.00 (no SD) Sway length: -38.6 mm (no SD) Sway speed: -2 mm/s (no SD) TUG: -2.15 s (no SD)	BBS: NS FICSIT-4: NS Sway length COG: NS Sway speed COG: NS TUG: NS
Park et al (2014)	40	E: 51.15 ± 14.81 C: 48.65 ± 12.81	E: 14.10 ± 11.40m C: 12.75 ± 9.60m	TT (sling) 16h, 8 weeks, 3x week, 30'	TT stable	**Standing balance** Sway area COG Sway length COG	Sway area: -51.5 mm² ± 61.1 Sway length: -97 mm ± 88	Sway area: -29.6 mm² ± 10.1 Sway length: -56 mm ± 46	Sway area COG: NS Sway length COG: NS
Yoo et al (2014)	24	E: 64.1 ± 9.6 C: 71.3 ± 8.42	E: 30.4 ± 13.5m 26.1 ± 12.9m	CT + TT (unstable board) 9h, 6 weeks, 3x/week, 30'	CT + TT	**Standing balance** BBS	BBS: 5.69 ± 1.03	BBS: 3.45 ± 1.12	BBS: p<0.001

Abbreviations**;** SD = Standard Deviations; NS = Not Significant; TIS = Trunk Impairment Scale; COG = centre of gravity; MAS = Motor Assessment Scale; BBS = Berg Balance Scale; 10MWT = 10 Minute Walking Test; FICSIT-4 = Frailty and Injuries: Cooperative Studies of Intervention Techniques ; BBA = Brunel Balance Assessment

Figures

Figure 1. Flow Chart

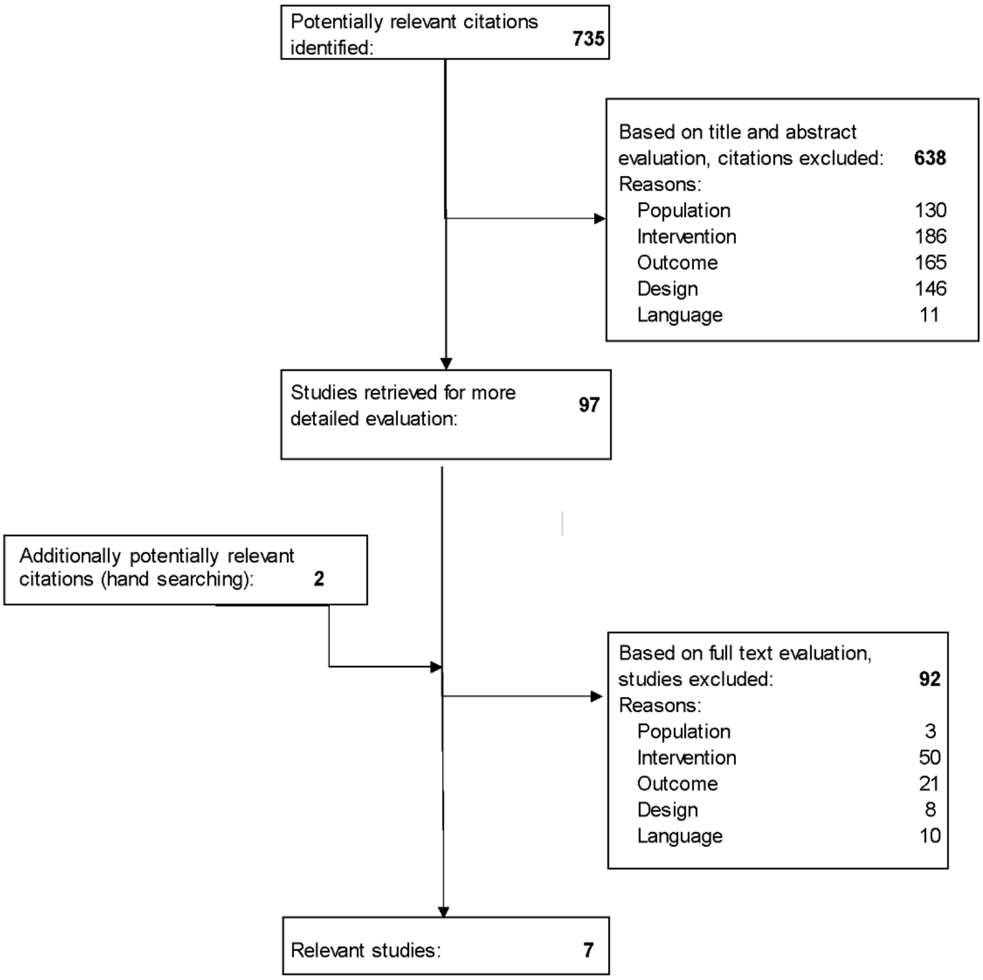

Figure 2. Forest plot Sitting Balance

	Unstable			Stable				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Jung et al 2016	4.83	2.17	15	2.42	2.35	15	37.0%	1.04 [0.27, 1.81]
Bae et al 2013	3.7	1.72	16	1.8	1.8	16	39.3%	1.05 [0.31, 1.80]
Karthikbabu et al 2011	7.93	1.28	15	4.87	1.25	15	23.7%	2.35 [1.39, 3.31]
Total (95% CI)			**46**			**46**	**100.0%**	**1.36 [0.89, 1.82]**

Heterogeneity: Chi² = 5.45, df = 2 (P = 0.07); I² = 63%
Test for overall effect: Z = 5.68 (P < 0.00001)

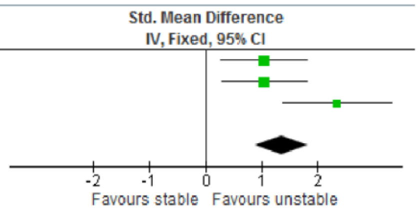

Figure 3. Forest plot Gait Performance

	Unstable			Stable				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Jung et al 2016	5.4	3.5	12	1.6	2.6	12	46.5%	1.19 [0.31, 2.07]
Karthikbabu et al 2011	4.67	1.29	15	2.8	1.15	15	53.5%	1.49 [0.67, 2.31]
Total (95% CI)			**27**			**27**	**100.0%**	**1.35 [0.75, 1.95]**

Heterogeneity: Chi² = 0.24, df = 1 (P = 0.63); I² = 0%
Test for overall effect: Z = 4.40 (P < 0.0001)