The effectiveness of trunk training on trunk control, sitting and standing balance and mobility post-stroke : a systematic review and meta-analysis

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The effectiveness of trunk training on trunk control, sitting and standing balance, and mobility post-stroke.

A systematic review and meta-analysis

Clinical messages:

- Large treatment effects were observed concerning the effectiveness of trunk training on dynamic trunk control, sitting and standing balance and mobility.
- Effectiveness of trunk training on static trunk control did not show any significant treatment effects.
- More research is necessary to determine the optimal modalities during rehabilitating and to distinguish between true motor recovery and compensation.

Introduction

Although improved dynamic balance and mobility after stroke can be achieved by increasing weight-bearing, muscle strength and postural control (1), the importance of proximal trunk control is often neglected. Exercises which were most effective included repetitive rising from a chair, walking uphill or at faster speeds on a treadmill (1). However, stroke patients require a minimal amount of walking ability to perform these types of exercises. In addition, they are mostly executed at later stages in the rehabilitation phase which means that less functional and structural cortical reorganization can be induced (2, 3). It is therefore necessary to examine rehabilitation strategies which enable improvement in dynamic balance and mobility in earlier stages of the rehabilitation with less functional requirements.

Trunk control and sitting balance are considered key predictors in functional outcome and hospital stay after stroke (4, 5). Several studies already investigated the effect of trunk training on trunk control, sitting and standing balance, and mobility (6-9). These reviews concluded that trunk training is able to improve trunk control and sitting balance assessed by the Trunk Impairment Scale. The overall treatment effect of both the dynamic and coordination subscale improved significantly compared to controls, while the static subscale did not. However, no consensus was reached concerning standing balance and mobility. Three reviews did not include measures of standing balance and mobility in their statistical analysis (6-8), while Sorinola et al (2014) used only three studies to obtain a summary estimate of the treatment effect without specifying different outcome measures

(9). As a results, evidence is still lacking concerning the effectiveness of trunk training on standing balance and mobility.

Moreover, in the recent years trunk rehabilitation received more attention resulting in a vast increase of the available literature. A concise and up-to-date overview of the effectiveness of trunk training on standing balance and mobility is currently lacking. We hypothesize that evidence will be presented that trunk training is able to improve trunk control, sitting and standing balance and mobility.

Methods

This systematic review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (10) and was registered in the PROSPERO database (n°CRD42018098857). Databases Pubmed/Medline, Web of Science, PEDro, Cochrane library, Rehab+, Rehabdata and Science Direct were searched until January 2019. A search strategy was defined based on Mesh-terms and free search terms such as “Cerebrovascular Disorders”, “Stroke”, “Hemiplegia”, “Trunk Exercises”, “Trunk Training”, “Balance”, “Torso”, “Walking” and “Gait”. The full search strategy can be found as supplementary material. After removing the duplicates by Endnote, titles and abstracts were independently screened by two of the four reviewers (M.V., C.v.d.W., Z.M., K.B.). Afterwards, full texts of the remaining studies and reference lists were screened. Disagreements were resolved by a fifth independent reviewer (T.V.C). Screening was performed based on the predetermined inclusion criteria (Table 1). Studies were excluded when (1) electromechanical devices such as virtual reality, electrical stimulation, vibration and/or biofeedback therapy were used in the experimental group, to make sure this kind of therapy is accessible for everyone; (2) exercises while standing or while walking were given; (3) two different types of trunk training were compared in the experimental and control group.

[Insert Table 1]

The primary outcome measures consisted of standing balance and mobility. First, standing balance describes the dynamics of body posture to prevent falling, assessment can be performed in both static or dynamic circumstances. Second, mobility assesses the quality of the gait pattern or the quantity of walking. All variables of interest can be assessed both clinically and biomechanically. The secondary outcome measure was trunk control and sitting balance assessing the ability to selectively move the trunk or stay balanced during static and dynamic situations.

Risk of bias of the included studies was assessed using the PEDro scale (11). Two of the four reviewers scored the studies independent from each other (M.V., C.v.d.W., Z.M., K.B.). Disagreements were resolved by a fifth independent reviewer (T.V.C). The PEDro score was divided into three categories: high quality = PEDro score 6-10, fair quality = PEDro score 4-5 and poor quality = PEDro score < 3 (12).

From the included studies of this review the following data were extracted: demographic data, subject characteristics, number of participants, outcome measures, intervention protocols and the relevant results of the studies. For creating the meta-analysis, the number of participants, mean differences and standard deviations were inserted in the template provided by *Review Manager 5.3 software* (The Nordic Cochrane Centre, Copenhagen, Denmark). When the necessary data was not available, authors were contacted to complete the data form. If authors did not respond, missing data were manually calculated using the Review manager calculator, if possible. Inverse variance was used as statistical method, a random effects model was used as analysis model and standardized mean differences (SMD) were calculated as the effect measure. Heterogeneity between the studies was assessed using I^2 statistics. 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 (13). Effect sizes were estimated and presented on pooled forest plots for trunk control and sitting balance, standing balance and mobility if at least two studies used the same outcome measure. Effect sizes were categorized as a standard mean effect size of 0 which represented no change, 0.2 representing a small effect, 0.5 representing a medium effect and 0.8 representing a large effect (14). Confidence intervals (CI) were set at 95%.

Results

Of the 1881 studies retrieved from all databases, 22 studies were included. The study selection process is provided in the flow chart (Figure 1). The mean PEDro score was six out of ten which corresponds with a low risk of bias (Table 2). Fourteen studies reached a high-quality score (15-28), while eight studies reached a fair-quality score (29-36). Most studies did not meet the criteria of blinding the subjects and therapist as this does not seem possible with respect to treatment. Additionally, blinding of assessors was not reported in the majority of cases. Therefore, a negative score was given for this item.

[Insert Figure 1]

[Insert Table 2]

In total 394 patients suffering from stroke were examined in the experimental group and 394 in the control group (Table 3). The mean age of the participants in the experimental group is 58 and 60 years in the control group. Time post stroke varied from 15 days to 47 months after stroke diagnosis. Ten studies examined the effect of additional trunk training compared to only conventional training or no therapy (15-17, 28, 29, 31, 32, 34-36). The remaining twelve studies examined the effect of trunk training compared to a control training program such as upper limb training (20, 27), conventional training (21, 22, 24, 26, 33), cognitive training (18, 19), general exercises (30) and stretching exercises (23), neuromuscular electrical stimulation (25). The majority of exercises consisted of core stability exercises such as bridging, dead bug position, upper and lower trunk flexion, extension and rotation, for the trunk training groups on both stable and unstable surfaces (15-17, 20, 21, 26-29, 33-36). Other studies implemented a sitting training protocol consisting of weight-shift (22, 23) or reaching exercises (18, 19, 31, 32). A final study used proprioceptive neuromuscular facilitation techniques to enhance trunk function (30). The amount of therapy varied from a total of 3 to 36 hours between studies. The outcome measures used to asses trunk control, sitting and standing balance and mobility can be found in Table 3. Three studies could not be included in the meta-analysis due to missing data (20, 25) and unique outcome measures (32).

[Insert Table 3]

First, Twenty studies assessed trunk control and sitting balance (15-28, 30-32, 34-36) of which the majority found significant effects on the total Trunk Impairment Scale SMD 1.34 (95% CI 0.96 to 1.71), the dynamic subscale SMD 1.33 (95% CI 0.95 to 1.71), the coordination subscale SMD 1.08 (95% 0.57 to 1.59) and reaching ability SMD 1.54 (95% CI 1.06 to 2.02) (Figure 2 and 3). However, the static subscale of the Trunk Impairment Scale did not result in a significant treatment effect SMD 0.18 (95% CI -0.09 to 0.45). Although significant differences were found for the Function in Sitting Test, the more static outcome measures such as the Trunk Control Test and Brunel Balance Assessment sitting subscale did not show significant differences between the experimental and control group.

[Insert Figure 2]

[Insert Figure 3]

Second, six studies investigated the effectiveness of trunk training on standing balance (15, 16, 24, 27, 33, 35) of which the majority of studies found significant effects on the Berg Balance Scale SMD 0.78 (95% CI 0.49 to 1.06), Tinetti Balance Subscale SMD 1.13 (95% CI 0.78 to 1.49) and Forward Reach SMD 0.51 (95% CI 0.04 to 0.98) (Figure 4). The remaining outcome measures assessing standing balance which resulted in significant between-group differences were the Four Test Balance Scale (27) and the Brunel Balance Assessment standing subscale (16). On the other hand the Romberg test with eyes open and eyes closed did not result in significant differences (27).

Third, eight studies assessed mobility measures as seen in Figure 5 (15, 16, 19, 21, 22, 24, 27, 29) of which the majority of studies found significant results on the Tinetti Gait Subscale SMD 1.20 (95% CI 0.82 to 1.57), Functional Ambulation Categories SMD 0.59 (95% CI 0.09 to 1.09), Walking Speed SMD 0.68 (95% CI 0.33 to 1.02) and Timed Up and Go Test SMD 0.77 (95% CI 0.30 to 1.23). The remaining outcome measures assessing mobility which resulted in significant between-group differences were the Brunel Balance Stepping subscale and Dynamic Gait Index. However, no between-group differences were observed for cadence, step length and stride length.

Fourth, four studies assessed both balance and mobility performance (16, 24, 27, 34), of which all studies found significant treatment effects on the Total Tinetti test SMD 1.21 (95% SMD 0.92 to 1.49), and Total Brunel Balance Assessement Scale SMD 1.48 (95% 0.76 to 2.21) (Figure 6). The two remaining outcome measures showing significant between-group differences were the Postural Assessment Scale for Stroke and the Brief-BESTest (16, 21).

[Insert Figure 4]

[Insert Figure 5]

In summary, the overall treatment effect was large for trunk control SMD 1.08 (95% CI 0.96 to 1.31), standing balance SMD 0.84 (95% CI 0.04 to 0.98), and mobility SMD 0.88 (95% CI 0.67 to 1.09). The level of heterogeneity was considerable for trunk control (I^2=76%), while not important for standing balance and mobility (I^2=13% and I^2=20%, respectively)

Discussion

This systematic review and meta-analysis included 22 studies, with a total of 788 stroke patients, and were deemed of high to medium quality. We found strong evidence that trunk training is able to improve trunk control, sitting and standing balance and mobility after sub-acute and chronic stroke. Our results comply with previous reviews concluding that trunk training is a good rehabilitation strategy for improving dynamic sitting balance (6-9). Moreover, this is the first meta-analysis, to our knowledge, examining the effectiveness of trunk training on standing balance and mobility in a sufficient amount of studies with specifications of the assessed outcome measures.

In accordance to previous studies, large treatment effects were observed for dynamic trunk control and sitting balance. On the other hand, the static subscale did not show any between-group differences. This might be due to a reported ceiling effect of the static subscale of the Trunk Impairment Scale or the inclusion criteria of the included studies, e.g. patient had to be able to sit for 30 seconds without support (37). However there was a considerable amount of heterogeneity in the results since twenty studies with different protocols were included in the meta-analysis. Due to the increased amount of available literature, large treatment effects were also found for standing balance and mobility. These carry-over effects are particularly interesting since they allow for preparation of stance and walking even though patients are not yet able to do this. As Knott et al. already stated in the 1940's when conceptualizing the proprioceptive neuromuscular facilitation techniques, proximal stability is prerequisite for distal mobility (38). In regard to the trunk, they stated that "in an efficient state the trunk provides appropriate proximal stability or controlled mobility to support optimal task or postural performance". Over the more recent years, many authors have acknowledged this concept (39-41). Although this concept is widely known, no attempt was made to explain these carryover effects. Only one study examined these improvements in a more biomechanical manner by assessing not solely walking speed but also stride length, step length and cadence (42). Although improvements in standing balance and mobility are seen, stroke survivors might improve their motor function by using compensatory strategies. Without taking into account the quality of a certain task, it is impossible to discriminate between "true recovery" and "compensation" of the basic motor patterns (43). Are we therefore seeing true trunk recovery or rather compensatory behaviour during standing and walking? To answer this question, kinematic, kinetic and electromyographic information should be collected to distinguish true motor recovery from compensation. A recent systematic review already suggested that trunk training seems to be effective in restoring symmetry in muscle thickness of the transversal abdominal muscles and improve the muscle activity of the internal oblique abdominis, which might explain the increased stability in the trunk (44). However, to explain the carry-over effects muscle activity should be investigated in greater detail.

There were a few limitations in this review that we must consider. Both sub-acute and chronic stroke participants were included in this review, since the recovery time of these groups differ, results were possibly influenced. Second, the heterogeneity between the studies was rather high when performing the meta-analysis, this is due to the great variety in training protocols. To minimize the heterogeneity we excluded several studies executing trunk training with different protocols: electromechanical devices, comparison of two types of trunk training, exercises in stance, etc. However, these studies might also have important conclusions concerning trunk training, yet they were not presented in this review. At last, 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. However, a recent systematic review only including Chinese articles found similar results to this review (45).

Additionally, to due the great amount of heterogeneity in the studies if was difficult to provide clinical recommendations as the majority of studies used different protocols: i.e. type of exercises, intensity, duration of treatment and support surface. However, attention should be given to the following observations. First, due to the limited amount of drop outs or adverse effects reported, trunk training is a safe rehabilitation strategy to perform in patients with diminished balance. Second, concerning the rehabilitation phase of patients, both sub-acute as chronic stroke patients were able to improve after trunk training. Yet, greater improvements were seen in the sub-acute group. Since the recovery time course of the trunk is similar to the recovery of the extremities, the first three months are critical for setting ideal circumstances for recovery (46). At last, regarding support surfaces, both stable and unstable surfaces resulted in greater test scores. Yet, unstable surfaces seem to result in greater improvements compared to stable ones (47). Future research should examine which modalities concerning type of exercise, duration and intensity are optimal during stroke rehabilitation.

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Conflict of interest:

The authors have no conflicts of interest to declare.

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Table 1. Inclusion criteria

Participants	Adult stroke survivors: ischemic or hemorrhagic
Outcome measures	Clinical or biomechanical assessments involving trunk function, sitting and standing balance, mobility
Comparison	Trunk training versus control/other training Standard care + trunk training versus standard care (+control/other training)
Intervention	Trunk exercises or other activities targeting the trunk while sitting/lying, to minimize the influence of lower extremity function. A similar definition for trunk training was used as in the review of Cabanas-Valdés et al. (2013) (6). Exercises could be performed either on a stable or unstable surface and had to include: • Reaching: performed beyond arm's length to enhance the truncal influence. • Core stability: consisting of task-specific movements of the upper and lower part of the trunk both in the supine and sitting, e.g. bridging, dead bug position, planking, etc. • Weight shifting: the pelvis shifted the body weight to the paretic side and back, aiming to encourage the experience of weight-bearing on the paretic side during sitting.
Language	Written in English, Dutch, French or German
Design	Randomized controlled trials or clinical trials investigating an experimental and control group

Table 2. Risk of bias assessment by the PEDro scale

Study	eligibility criteria	Random allocation	Concealed allocation	Baseline comparability	Blind subjects	Blind therapists	Blind assessors	Adequate follow-up	Intention-to-threat	Between-group comparisons	Point estimates and variability	TOTAL (10)
An et al. (2016) (15)	+	+	+	+	-	-	+	+	-	+	+	**7**
Cabanas-valdes et al. (2015) (16)	+	+	+	+	-	-	+	+	-	+	+	**7**
Chan et al. (2015) (17)	-	+	+	+	-	-	+	+	+	+	+	**8**
Chung et al. (2013) (29)	-	+	-	+	-	-	-	+	-	+	+	**5**
Dean et al. (1997) (18)	+	+	+	+	-	-	+	+	-	+	+	**7**
Dean et al. (2007) (19)	+	+	+	+	-	-	+	-	+	+	+	**7**
Dell'Uomo et al. (2017) (20)	+	+	-	+	-	-	+	+	-	+	+	**6**
Haruyama et al. (2016) (21)	+	+	-	+	-	-	+	+	-	+	+	**6**
Jung et al. (2014) (22)	+	+	+	+	-	-	+	+	-	+	+	**7**
Jung et al. (2016) (23)	+	+	+	+	-	-	+	+	-	+	+	**7**
Karthikbabu et al. (2018) (24)	-	+	+	+	-	-	+	-	+	+	+	**7**
Kim et al. (2011) (30)	-	+	-	+	-	-	-	-	-	+	+	**4**
Ko et al. (2016) (25)	+	+	-	+	-	-	+	+	-	+	+	**6**
Lee et al (2011) (31)	+	+	-	+	-	-	-	+	-	+	+	**5**
Mudie et al. (2002) (32)	+	+	+	-	-	-	-	-	-	+	+	**4**
Rose et al. (2016) (26)	+	+	+	-	-	-	-	+	-	+	+	**6**
Saeys et al. (2012) (27)	+	+	+	+	-	-	+	+	-	+	+	**7**
Sun et al. (2016) (33)	+	+	+	-	-	-	-	+	-	+	-	**4**
Verheyden et al. (2009) (28)	+	+	-	+	-	-	+	+	-	+	+	**6**
Vijaya Kumar et al. (2011) (34)	+	+	-	+	-	-	+	-	-	+	+	**5**
Yoo et al. (2010) (35)	+	+	-	+	-	-	-	+	-	+	+	**5**
Yu et al. (2013) (36)	+	-	-	+	-	-	-	+	-	+	+	**4**