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REVIEW ARTICLE

# The Efficacy of Trunk Training Treatment Intensities on Trunk Control of Stroke Patients: A Systematic Review, Meta-Analysis and Meta-Regression

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## *ABSTRAK*

*Kajian ini bertujuan untuk menilai keberkesanan intensiti rawatan latihan batang tubuh pada kawalan batang tubuh pesakit strok dengan skor Skala Kerosakan Batang Tubuh (TIS). Kajian kepustakaan berstruktur telah dilakukan dalam beberapa pangkalan data daripada artikel diindeks pertama sehingga Disember 2022, termasuk PubMed, Web of Science, PEDro, Perpustakaan Cochrane dan Scopus. Selain itu, pemilihan kajian telah disiasat mengikut garis panduan PRISMA. Hanya ujian terkawal rawak yang mengkaji keberkesanan latihan batang tubuh pada kawalan batang tubuh (diukur oleh TIS selepas strok) dimasukkan. Sebanyak 25 ujian dengan 976 pesakit strok telah dinilai. Sementara itu, tujuh kajian diklasifikasikan sebagai risiko berat sebelah yang tinggi. Tanpa mengira kaedah latihan dan kualiti kajian, kesan yang besar lebih berpihak kepada kumpulan latihan batang tubuh berbanding kumpulan kawalan. Analisis kepekaan mendedahkan kesan besar yang memihak kepada latihan batang tubuh pada kawalan batang tubuh [SMD = 1.16 (95% CI: 0.93-1.39); p<0.00001, I2 = 80%]. Selepas itu, tempoh rawatan latihan batang tubuh yang paling berkesan ialah 10 jam latihan kestabilan teras untuk penambahbaikan kawalan batang tubuh [SMD = 3.20 (95% CI: 2.25-4.15)]. Analisis meta-regresi tidak menunjukkan bukti kukuh intensiti rawatan latihan batang tubuh pada saiz kesan. Latihan batang tubuh adalah berkesan dalam pemulihan batang tubuh. Walau bagaimanapun, latihan batang tubuh tertentu diperlukan untuk fasa strok yang berbeza. Menariknya, saiz kesan telah diperbesarkan secara bermakna dengan menambah 15 minit latihan kestabilan teras kepada terapi konvensional (lima sesi seminggu selama lapan minggu campur tangan). Keputusan ini berguna dalam menentukan bilangan sesi untuk pemulihan batang tubuh yang berkesan.*

*Kata kunci:* *Pemulihan; penyakit sistem saraf; penyakit jantung; strok*

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## ABSTRACT

This study aims to assess the efficacy of trunk training treatment intensities on trunk control of stroke patients with the Trunk Impairment Scale (TIS) score. A structured literature search was performed in several databases from the first indexed article until December 2022, including PubMed, Web of Science, PEDro, Cochrane Library, and Scopus. In addition, the study selection was investigated following the PRISMA guideline. Only randomised controlled trials that examined the trunk training effectiveness on trunk control (measured by the TIS after stroke) were included. A total of 25 trials with 976 stroke patients were evaluated. Meanwhile, seven studies were classified as high bias risk. Irrespective of the training mode and methodology quality, the large effects favored trunk training compared to the control group. The sensitivity analysis revealed a large effect in favour of trunk training on trunk control [SMD = 1.16 (95% CI: 0.93-1.39); p<0.00001, I2 = 80%]. Subsequently, the most effective trunk training treatment duration was 10 hours of core stability exercise for trunk control improvement [SMD = 3.20 (95% CI: 2.25-4.15)]. The meta-regression analysis demonstrated no strong evidence of trunk training treatment intensities on the effect sizes. Trunk training was effective in trunk rehabilitation. Nonetheless, specific trunk training was required for different stroke phases. Interestingly, the effect size was meaningfully enlarged by adding 15 minutes of core stability exercise to the conventional therapy (five sessions per week over eight weeks of intervention). This result was useful in determining the number of sessions for effective trunk rehabilitation.


Keywords: Cardiovascular diseases; nervous system diseases; rehabilitation; stroke

## INTRODUCTION

Trunk impairment is a major stroke concern as a motor deficit in the trunk affects trunk muscle performance bilaterally (Fujiwara et al. 2001). The trunk is a dominant feature and the largest part of the body. Thus, proximal trunk stability is crucial for the movement, balance, and daily activities of the distal extremities. The trunk is also essential for enabling appropriate weight shifts and regulating the movement of the trunk against gravity (Karthikbabu et al. 2018). Nevertheless, trunk impairment can produce postural disturbance, balance dysfunction, and reduced mobility in patients with chronic stroke (Verheyden et al. 2006). Therefore, trunk control has been identified as a key predictor of functional prognosis and hospital stay following stroke (Hsieh et al. 2002; Verheyden et al. 2007).

According to meta-analyses of the Trunk Impairment Scale (TIS) and Trunk Control Test (TCT), trunk training can improve trunk control (Alhwoaimel et al. 2019; Cabanas-Valdes et al. 2013; Van Criekinge et al. 2019). It remains unclear which specific trunk training treatment intensity is more effective for the rehabilitation of stroke survivors. Furthermore, previous studies were more concerned with the treatment duration (defined by how long a patient should be treated with certain procedures) for any given problem of trunk training (Mason 2009). In a study, the most effective treatment duration of trunk training was 16 hours with a treatment frequency of 30 minutes per session (four sessions per week over eight weeks) (Cabanas-Valdes et al. 2013). On the contrary, a recent study reported that a total of 13.5 trunk training hours demonstrated a highly significant effect with standardised mean differences (SMD) of 3.08 (Alhwoaimel et al. 2019). This value was observed on trunk performance outcome measures, in which the treatment consisted of 45 minutes per session (six sessions per week over three weeks of intervention) (Vijayakumar et al. 2011). Additionally, this study discovered that the Bobath-based trunk training with a treatment duration of 36 hours produced no significant effect ($p$>0.05) on trunk control (Kilinc et al. 2016). Thus, the ineffectiveness of additional treatment duration was evident in this study.

Only several studies have investigated the treatment intensity or strength, which refers to how an intervention is designed and delivered (in what form it could work) (Daly et al. 2007). Moreover, it is one of the parameters to improve treatment effectiveness (Warren et al. 2007). The length of sessions, the frequency of sessions per week, the number of treatment weeks overall (Codding & Lane 2015), complexity of the treatment by adding or removing components (Codding et al. 2011; Daly et al. 2007; Yeaton & Sechrest 1981), or the different types of components delivered (Swanson & Sachse-Lee 2000), can have an impact on the treatment intensity. For instance, a study that used dual-task activities and extensive multiplanar trunk training over the course of 12 intervention weeks found improvement. As a result, the study found that functional recovery, balance, and trunk control had all improved (Vaughn et al. 2010). Practise of a particular activity with a variety of obstacles or variants added to a training regimen also improved the performance of a motor task (Ahmed et al. 2021; Page et al. 2004).

Previous meta-analytical reviews mostly focused on trunk training's impact on trunk control, with little information on the factors that influence it. Considering relevant treatment intensity, these factors included the appropriate intervention, for whom, and under what circumstances efficient outcomes could occur. Therefore, this study extended the Cochrane review (first published in 2013) (Cabanas-Valdes et al. 2013) and previously updated in 2019 (Alhwoaimel et al. 2019; Van Criekinge et al. 2019). This present study aims to update the effects of trunk training following stroke, evaluate the intensity of trunk training therapy using TIS score and conduct a meta-regression analysis in regard to treatment intensity as the factor.

There were 25 papers totalling 976 stroke patients included in this review. Randomised control trial data was enough to enable meta-analysis of trunk training treatment intensities. The study focused on the most effective trunk training treatment intensities. Future research directions were suggested to enable the most effective trunk control recovery in stroke patients. Moreover, new and notable studies were highlighted.

## MATERIALS AND METHODS

### Search Strategy

This systematic review was carried out in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al. 2021) and the Cochrane Handbook for Systematic Reviews guideline (Higgins & Thomas 2020). From the earliest indexed publication through December 2022, this study thoroughly searched databases including PubMed/MEDLINE, Web of Science, Physiotherapy Evidence Database (PEDro), Cochrane Library, and Scopus. The following MeSH terms and keywords with Boolean conjunctions (OR/AND) were applied as follows:

*"[stroke/or poststroke/or post-stroke/ OR "cerebrovascular accident"] AND [trunk training/or trunk exercise/or trunk training exercise], AND [rehabilitation/ or therapy/or physical therapy], [trunk control/or trunk performance]"*

The complete search strategy by the PRISMA 2020 statement was presented in Figure 1. Three independent reviewers examined the title and abstract after removing duplicates using Endnote (MIZR, ZMR, and MFR). Subsequently, the full-text articles were retrieved, and disagreements were resolved by a fourth independent reviewer (JNA).

### Study Selection

Based on the PICOS approach, the studies were selected if they met the following inclusion criteria (Liberati et al. 2009) (Table 1). Studies were not included if any of the following conditions hold true: (i) the outcome measure excluded trunk performance; (ii) electromechanical devices, such as virtual or augmented reality, electrical stimulation, vibration, and biofeedback therapy, were exclusively used; (iii) injection therapy or administered needling (acupuncture) was used. Unfortunately, only 25 studies were considered and studies with small number of samples (n = 16-84) may lead to the biasness. However, these well-defined criteria clearly outlined the characteristics and conditions of the stroke population eligible for this systematic review. Hence, participants who shared similar baseline characteristics will help overcome the bias and reduce heterogeneity.

The meta-analysis, sensitivity analysis, and meta-regression were performed when relevant data were available.

### Methodological Quality Assessment of the Studies

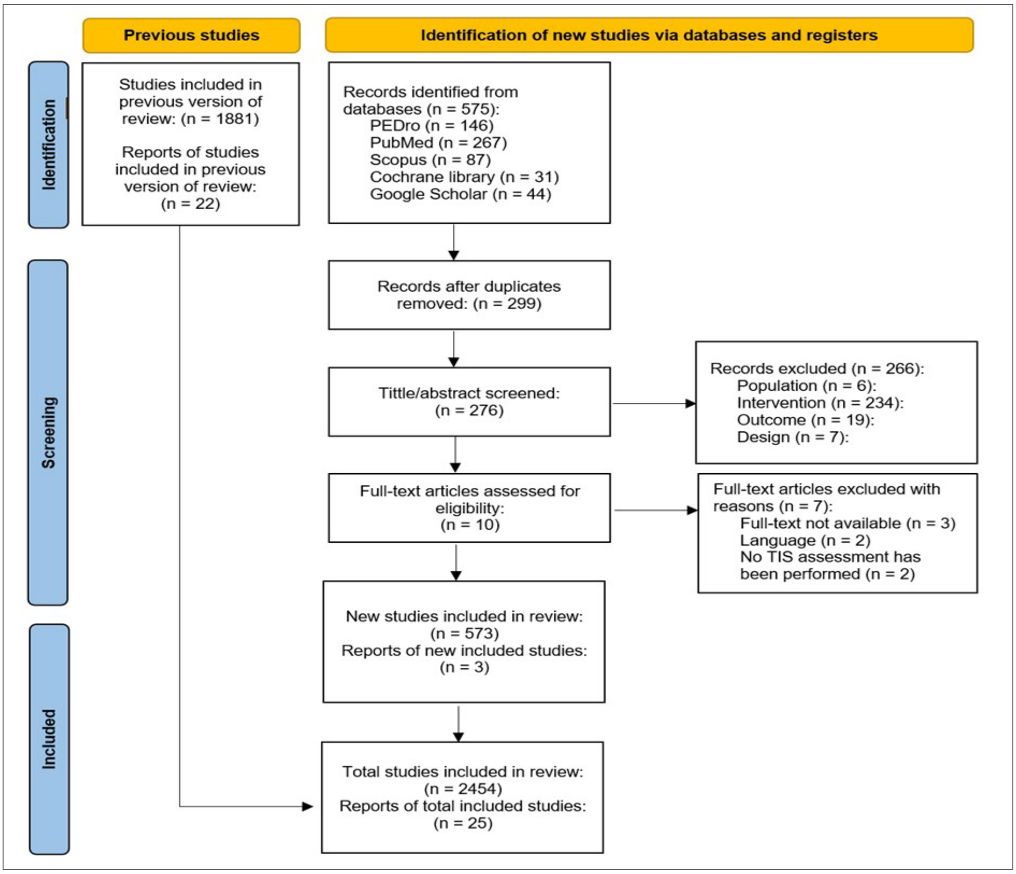


FIGURE 1: PRISMA flow chart

Using the risk of bias (ROB) score, the methodological calibre of each eligible trial was evaluated. Following the Cochrane Handbook version 5.1.0 tool (Cochrane, London, UK), the ROB was independently assessed by four authors (JNA, MIZR, ZMR, and MFR) (Higgins & Thomas 2020). Two reviewers (JNA and ZMR) extensively discussed the discordant study ratings to come to a decision. Seven domains were considered and the ROB plot was acquired with the Risk-of-bias Visualisation (*robvis*) tool to generate high-quality figures that summarised the ROB statement (McGuinness & Higgins 2021) (Figure 2).

Trials were categorised into three ROB scores; high risk (high ROB in at least one domain or some concerns for multiple domains), unclear (some concerns in at least one domain, but not to be high ROB for any domain) and low risk (low ROB for all domains).

## Data Extraction and Categorisation

A five-sectioned table was utilised to extract the following data from the included studies as follows; (i) study data; (ii) participants' characteristics; (iii) intervention protocols; (iv) trunk

TABLE 1: Summary of the inclusion criteria

| | |
|---|---|
| **Population** | Adult stroke survivors (age 18 or older): ischaemic or haemorrhagic |
| **Interventions** | Trunk training or other activities targeting the trunk while sitting/lying. A similar definition for trunk training was also used in the review of Cabanas-Valdés et al. [6]. Exercises had to include:<br>· Reaching: performed beyond arm's length to enhance the truncal influence.<br>· Core stability: consisting of task-specific movements of the upper and lower parts of the trunk both in the supine and sitting, for example, bridging, dead bug position, planking and so on.<br>· 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.<br>· Any exercises/rehabilitation that involved or related to trunk motion (flexion, extension, rotation, lateral) that resulted in trunk performance, balance, mobility, and ADL will be considered. |
| **Comparators** | The intervention involved any form of balance exercise, core/or trunk strengthening exercise and any form of trunk exercise with or without conventional physiotherapy (CPT).<br>Interventions not performed with robotics or functional electrical stimulation alone |
| **Main outcome** | Clinical or biomechanical assessments involving trunk control as measured by TIS |
| **Study design** | Randomised controlled trials or clinical trials investigating experimental and control groups |
| **Language** | Written in English |


FIGURE 2: Cochrane risk of bias summary

training treatment intensity; and (v) trunk training treatment duration of the studies.

The study characteristics of trunk training were presented in Table 2. Six different comparisons were performed in the included studies of the present review. The majority of studies compared trunk training with traditional therapy (An & Park 2017; Büyükavcı et al. 2016; Cabanas-Valdés et al. 2016; Cabanas-Valdés et al. 2017; de Sèze et al. 2001; Haruyama et al. 2017; Lee et al. 2012; Mahmood et al. 2022; Rose & Vasanthan 2016; Verheyden et al. 2009; Vijayakumar et al. 2011; Yoo et al. 2010), sham treatment (Saeys et al. 2012), or just standard care (Yu & Park 2013). Meanwhile, several studies compared the efficacy of stable and unstable support surfaces during trunk training (Bae et al. 2013; Jung et al. 2014; Jung et al. 2016; Jung et al. 2021; Karthikbabu et al. 2022; Karthikbabu et al. 2011), high-intensity multiplanar coupled with dual-task (HIMTD) (Ahmed et al. 2021) and functional electrical stimulation in conjunction with trunk training (Chan et al. 2015; Ko et al. 2016; Shin et al. 2016). Several different ways were utilised in the studies to describe the treatment intensity. The variable values were categorised into groups to compare the underlying treatment intensities (Table 2).

## Statistical Analysis and Bias Assessment

The Cochrane Review Manager (RevMan) 5.4.1 software (The Nordic Cochrane Centre, Copenhagen, Denmark) created a meta-analysis with data from the number of participants, mean differences, and standard deviations. When the necessary data were unavailable, the RevMan calculator was utilised to calculate the missing data manually. The software calculated the inverse-variance method using the random effects model (Deeks et al. 2019). For the outcome categories of trunk control and treatment intensities among stroke patients, several forest plots (Figures 3 & 4) and a summary table (Table 3) were generated. As a measure of treatment efficacy, the identification of SMD with 95% confidence interval (CI) results could either be positive or negative. $I^2$ statistics were then used to evaluate the heterogeneity between the trials. Likewise, the Cochrane guidelines interpreted heterogeneity (Higgins & Thomas 2020). Regarding trunk control, stroke stages, and treatment intensity (where at least two trials used the same outcome measure), the effect sizes were computed and displayed on the forest plots.

The following five essential criteria were used to evaluate the subgroup analyses from the generated forest plots (Richardson et al. 2019). There was an interaction (subgroup difference that was statistically significant), the covariate distribution (the number of trials and participants that made up each subgroup), the likely existence of the interaction or lack of interaction, the significance of the interaction or lack of interaction, and the potential of confounding.

As most of the trials were from the unclear-risk score, sensitivity analysis

TABLE 2: Summary of the studies characteristics of trunk training

| Study | Participants | | | Intervention | | Trunk outcome measure | Trunk training treatment intensity | Trunk training treatment duration / hour |
|---|---|---|---|---|---|---|---|---|
| | N | Age / year | TPs / month | Experimental | Control | | | |
| An & Park SD 2017 | EG: 15<br>CG: 14 | EG: 59.73 ± 8.94<br>CG: 57.07 ± 17.17 | EG: 9.07 ± 3.47<br>CG: 8.93 ± 2.30 | TT (30 min) + CT (30 min mins/day, 5x /week for 4 weeks) | CT (30 min mins/ day, 5x /week for 4 weeks) | TIS | AT: 30 min<br>No. of session: 5<br>No. of total weeks: 4<br>Complexity: -<br>Varying the TT: - | 10 |
| Büyükavcı et al. 2015 | EG: 32<br>CG: 32 | EG: 62.6 ± 10.5<br>CG: 63.6 ± 10.4 | EG: 33.4 ± 11.4 days<br>CG: 38.5 ± 19.9 days | TT (2 hours/day, 5 days/week, for 3 weeks) + CT (2-3 hr/session, 5 days/ week, for 3 weeks) | CT (2-3 hr/session, 5 days/week, for 3 weeks) | TIS | AT: 120 min<br>No. of session: 5<br>No. of total weeks: 3<br>Complexity: Reaching<br>Varying the TT: - | 30 |
| Lee et al. 2012 | EG: 14<br>CG: 14 | EG: 59.0 ± 11.0<br>CG: 62.3 ± 14.2 | EG: 34.4 ± 25.4<br>CG: 33.6 ± 15.9 | TT (30 min, 3x / week for 6 weeks) + CT (60 min, 5x/ week for 6 weeks) | CT (60 min, 5x / week, for 6 weeks) | TIS | AT: 30 min<br>No. of session: 5<br>No. of total weeks: 6<br>Complexity: -<br>Varying the TT: - | 9 |
| Saeys et al. 2012 | EG: 18<br>CG: 15 | EG: 61.94 ± 13.83<br>CG: 61.07 ± 9.01 | EG: 38.72 ± 15.09 days<br>CG: 32.07 ± 25.98 days | TT (16 hr) + CT (NA) | Sham treatment (16 hr) + CT (NA) | TIS | AT: 30 min<br>No. of session: 4<br>No. of total weeks: 8<br>Complexity: -<br>Varying the TT: | 16 |
| Verheyden et al. 2009 | EG: 17<br>CG: 16 | EG: 55 ± 11<br>CG: 62 ± 14 | EG: 53 ± 24 days<br>CG: 49 ± 28 days | TT (30 min/day, 4x /week, for 5 weeks = 10 hr) + CT (NA) | CT (NA) | TIS | AT: 30 min<br>No. of session: 4<br>No. of total weeks: 5<br>Complexity: -<br>Varying the TT | 10 |
| Vijayakumar et al. 2011 | EG: 10<br>CG: 10 | EG: 59.5 ± 12.09<br>CG: 57.8 ± 13.49 | EG: 15.0 ± 6.16 days<br>CG: 15.8 ± 10.69 days | TT (45 min/day, 6x /week, for 3 weeks) + CT (NA) | CT (NA) | TIS | AT: 45 min<br>No. of session: 6<br>No. of total weeks: 3<br>Complexity: -<br>Varying the TT: - | 13.5 |

| Study | Participants | | | Intervention | | Trunk outcome measure | Trunk training treatment intensity | Trunk training treatment duration / hour |
|---|---|---|---|---|---|---|---|---|
| | N | Age / year | TPs / month | Experimental | Control | | | |
| Haruyama et al. 2017 | EG: 16<br>CG: 16 | EG: 67.56 (10.11)<br>CG: 65.63 (11.97) | EG: 66 (49.25, 91.5) days<br>CG: 72 (48.25, 93.5) days | TT: CSE (20 min) + CT (60 min/ day, 5x /week, 4 weeks) | CT (60 min/day, 5x/week, 4 weeks) | TIS | AT: 20 min<br>No. of session: 5<br>No. of total weeks: 4<br>Complexity: CSE<br>Varying the TT: - | 6.67 |
| Cabanas-Valdés et al. 2015 | EG: 40<br>CG: 39 | EG: 74.92 (10.70)<br>CG: 75.69 (9.40) | EG: 25.12 (17.30) days<br>CG: 21.37 (16.00) days | TT: CSE (15 min/ day) + CT (1hr/ day, 5 day/week, 5 week) | CT (1 hr/day, 5x/ week, for 5 weeks) | TIS | AT: 15 min<br>No. of session: 5<br>No. of total weeks: 5<br>Complexity: CSE<br>Varying the TT: | 6.25 |
| Cabanas-Valdés et al. 2017 | EG: 32<br>CG: 36 | EG: 75.81 (9.06)<br>CG: 75.08 (11.05) | EG: 59.22 (16.06) days<br>CG: 62.70 (17.60) days | TT: CSE (15 min/ day, 5 day/week, for 5 weeks) + CT (1 hr/day, 5x/ week, for 5 weeks) | CT (1 hr/day, 5x/ week, for 5 weeks) | TIS | AT: 15 min<br>No. of session: 5<br>No. of total weeks: 5<br>Complexity: CSE<br>Varying the TT: | 6.25 |
| Yoo et al. 2010 | EG: 28<br>CG: 31 | EG:59.61 ± 18.16<br>CG: 61.77 ± 12.58 | EG: 42.86 ± 35.08 days<br>CG: 48.03 ± 29.45 days | TT: CSP (30 min/ day, 3 day/weeks, 4 weeks) + CT | CT | TCT<br>TIS | AT: 30 min<br>No. of session: 3<br>No. of total weeks: 4<br>Complexity: CSP<br>Varying the TT: - | 6 |
| Yu & Park 2013 | EG: 10<br>CG: 10 | EG: 50.00 ± 5.53<br>CG: 52.64 ± 4.56 | EG: 25.85 ± 9.99<br>CG: 30.96 ± 7.67 | TT: CSE (30 min, 5x /week, for 4 weeks) + SC | SC | TIS | AT: 30 min<br>No. of session: 5<br>No. of total weeks: 4<br>Complexity: CSE<br>Varying the TT: - | 10 |
| Mahmood et al. 2022 | EG: 20<br>CG: 21 | EG: 57.10 ± 6.28<br>CG: 54.95 ± 6.35 | NA | TT: CSE (15 min) + CT (40 min/day, 5 times/week for 8 weeks) | CT (40 min/day, 5 times/week for 8 weeks) | TIS | AT: 15 min<br>No. of session: 5<br>No. of total weeks: 8<br>Complexity: CSE<br>Varying the TT: - | 10 |

| Study | Participants | | | Intervention | | Trunk outcome measure | Trunk training treatment intensity | Trunk training treatment duration / hour |
|---|---|---|---|---|---|---|---|---|
| | N | Age / year | TPs / month | Experimental | Control | | | |
| Park et al. 2019 | EG: 14<br>CG: 15 | EG: 56.23 ± 13.74<br>CG: 57.13 ± 11.73 | EG: 9.21 ± 4.95<br>CG: 12.93 ± 6.05 | TT: LATE (30 min/ day, 5 days/week, for 4 weeks) + CT (30 min) | CT (30 min, 2 / day, 5 days/week, for 4 weeks) | TIS | AT: 30 min<br>No. of session: 5<br>No. of total weeks: 4<br>Complexity: LATE<br>Varying the TT: - | 10 |
| Ahmed et al. 2021 | EG: 42<br>CG: 42 | EG: 61.21 ± 7.78<br>CG: 62.21 ± 8.20 | EG: 7.21 ± 3.27<br>CG: 7.30 ± 3.03 | TT: HIMTD (45 min) + CT (1hr) for 5x /week, in 3 months | TT: SC (45 min) + CT (1hr) for 5 / week, in 3 months | TIS | AT: 45 min<br>No. of session: 5<br>No. of total weeks: 12<br>Complexity: HIMTD<br>Varying the TT: TT + Dual task | 27 |
| Bae et al. 2013 | EG: 8<br>CG: 8 | EG: 52.4 ± 7.6<br>CG: 53.4 ± 5.8 | EG: 18.1 ± 4.2<br>CG: 17.9 ± 4.3 | TT: unstable-surface (30 min, 5x/week for 12 weeks) | TT: stable-surface (30 min, 5 /week for 12 weeks) | TIS | AT: -<br>No. of session: 5<br>No. of total weeks: 12<br>Complexity: Support surface<br>Varying the TT: - | 30 |
| Rose & Vasanthan 2016 | EG: 12<br>CG: 12 | EG: 57.08 ± 2.8<br>CG: 56.66 ± 3.12 | EG: 7.2 ± 2.5<br>CG: 5.6 ± 2.2 | TT: CSP (45 min, for 14 days over a period of 4 weeks, 3 sets each exercise/session, with 8 to 10 repetition) | CT (3 set/each exercise/session/ alternate day/4 week) | TIS | AT: -<br>No. of session: 14 days<br>No. of total weeks: 4<br>Complexity: Strengthening exercise<br>Varying the TT: - | 10.5 |
| Jung et al. 2016 | EG: 12<br>CG: 12 | EG: 58.9 ± 11.0<br>CG: 60.7 ± 7.8 | EG: 8.0 ± 3.2<br>CG: 8.4 ± 2.4 | TT: unstable-surface (30 min, 5x/week, for 4 weeks) | TT: stable surface (30 min, 5 /week, for 4 weeks) | TIS | AT: -<br>No. of session: 5<br>No. of total weeks: 4<br>Complexity: Support surface (Balance pad)<br>Varying the TT: - | 10 |

| Study | Participants | | | Intervention | | Trunk outcome measure | Trunk training treatment intensity | Trunk training treatment duration / hour |
|---|---|---|---|---|---|---|---|---|
| | N | Age / year | TPs / month | Experimental | Control | | | |
| Jung et al. 2021 | EG: 12<br>CG: 12 | EG: 61.33 ± 4.89<br>CG: 64.22 ± 5.67 | EG: 18.71 ± 1.59 days<br>CG: 17.86 ± 1.54 days | TT: unstable-surface (30 min/day, 5 days/weeks, 3 weeks) + CT | TT:stable-surface (30 min/day, 5 days/weeks, 3 weeks) + CT | TIS | AT: 30 min<br>No. of session: 5<br>No. of total weeks: 3<br>Complexity: Support surface (3D space balance)<br>Varying the TT: - | 7.5 |
| Karthikbabu et al. 2011 | EG: 15<br>CG: 15 | EG: 59.8 ± 10.5<br>CG: 55.0 ± 6.5 | EG: 11.8 ± 8.1 days<br>CG: 12.1 ± 7.5 days | TT: unstable-surface (1 hr/day, 4 days/weeks, 3 weeks) + CT | TT:stable-surface (1 hr/day, 4 days/weeks, 3 weeks) + CT | TIS | AT: 60 min<br>No. of session: 4<br>No. of total weeks: 3<br>Complexity: Support surface (physio ball/ physio plinth)<br>Varying the TT: - | 12 |
| Karthikbabu et al. 2022 | EG: 28<br>EG: 28<br>CG: 28 | EG: 56.9 ± 12.1<br>EG: 53.4 ± 13.9<br>CG: 54.6 ± 12.7 | EG: 13.2 ± 12.9<br>EG: 13.1 ± 15.7<br>CG: 14.8 ± 10.9 | (a) TT: CSE (unstable support surface) + gait training (15 min) + obstacle-course walking (1 hr/day, 3 days/week, 6 weeks)<br>(b) TT: CSE (stable support surface) + gait training (15 min) + obstacle-course walking (1 hr/day, 3 days/ week, 6 weeks) | CT (1 hr/day, 3 days/week, 6 weeks) | TIS | AT: 15 min<br>No. of session: 3<br>No. of total weeks: 6<br>Complexity: Support surface<br>Varying the TT: CSE + Gait training | 4.5 |
| Ko et al. 2016 | EG: 10<br>CG: 10 | EG: 58.5<br>CG: 65.5 | EG: 11 days<br>CG: 8.5 days | TT: CSP + tNMES (3x/ week, 20 min/day for 3 weeks) | TT: CSP (3x/ week, 20 min/day for 3 weeks) | TIS | AT: 20 min<br>No. of session: 3<br>No. of total weeks: 3<br>Complexity: CSP/ Electrical stimulation<br>Varying the TT: CMS +tNMES | 3 |

| Study | Participants | | | Intervention | | Trunk outcome measure | Trunk training treatment intensity | Trunk training treatment duration / hour |
|---|---|---|---|---|---|---|---|---|
| | N | Age / year | TPs / month | Experimental | Control | | | |
| Chan et al. 2015 | EG: 13<br>CG: 12 | EG: 56.3 ± 7.4<br>CG: 59.3 ± 10.4 | EG: 41.8 ± 28.73.1<br>CG: 47.3 ± 29.8 | (a) TT: TENS (1hr/day, 5x/week for 6 weeks)<br>(b) TT: TENS (placebo) (1 hr/day, 5x/week for 6 weeks) | TT: TENS (placebo) (1 hr/ day, 5x/week for 6 weeks) | TIS | AT: -<br>No. of session: 5<br>No. of total weeks: 6<br>Complexity: Electrical stimulation<br>Varying the TT: TENS+TT / Placebo TENS+TT / Placebo TENS | 30 |
| Jung et al. 2014 | EG: 9<br>CG: 8 | EG: 51.9 ± 10.3<br>CG: 57.9 ± 8.5 | EG: 15.3 ± 9.5<br>CG: 14.4 ± 11.2 | TT: unstable-surface (30 min, 5x/week for 12 weeks) | CT (30 min, 5x/ week for 12 weeks) | TIS | AT: -<br>No. of session: 5<br>No. of total weeks: 4<br>Complexity: Support surface<br>Varying the TT: - | 10 |
| Kılınç et al. 2016 | EG: 12<br>CG: 10 | EG: 55.91 ± 7.92<br>CG: 54 ± 13.64 | EG: 58.66 ± 55.68<br>CG: 67.20 ± 43.17 | TT: Bobath concept (1hr, 3x/week for 12 weeks) | Strengthening, stretching and range of motion exercise (1hr, 3x/week for 12 weeks) | TIS | AT: -<br>No. of session: 3<br>No. of total weeks: 12<br>Complexity: Bobath concept<br>Varying the TT: - | 36 |
| Shin et al. 2016 | EG: 12<br>CG: 12 | EG: 57.75 ± 14.03<br>CG: 59.25 ± 9.75 | EG: 17.58 ± 10.04<br>CG: 15.17 ± 7.13 | SPVFTCT (20 min) + CT (20 min, 3x/week for 4 weeks) | CT (20 min, 3x/ week for 4 weeks) | TIS | AT: 20 min<br>No. of session: 5<br>No. of total weeks: 4<br>Complexity: SPVFTCT<br>Varying the TT: - | 4 |

AT: Additional time; CG: Control group; CSE: Core stability exercise; CSP: Core/trunk strengthening program; CT: Conventional physical therapy; EG: Experimental group; HIMTD: high-intensity multiplanar trunk training coupled with dual-task; LATE: land-based and aquatic therapy program; NA: Not available; SC: Standard care; SPVFTCT: Smartphone-based visual feedback trunk control training; TENS: Transcutaneous electrical nerve stimulation; tNMES: trunk neuromuscular electrical stimulation; TIS: Trunk Impairment Scale; TT: Trunk training.

| Study or Subgroup | Trunk training Mean | Trunk training SD | Trunk training Total | Control Mean | Control SD | Control Total | Weight | Std. Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| **1.1.1 TIS SSB** | | | | | | | | |
| Jung KS et al. 2016 | 0.58 | 0.79 | 12 | 0.67 | 1.07 | 12 | 1.6% | -0.09 [-0.89, 0.71] |
| Haruyama K et al. 2017 | 0.63 | 1.41 | 16 | 0.69 | 1.25 | 16 | 1.7% | -0.04 [-0.74, 0.65] |
| Ahmed U et al. 2021 | 1.26 | 1.1017 | 42 | 1.3 | 1.1017 | 42 | 1.9% | -0.04 [-0.46, 0.39] |
| An SH and Park SD 2017 | 0.2 | 0.41 | 15 | 0.21 | 0.43 | 14 | 1.6% | -0.02 [-0.75, 0.71] |
| Saeys W et al. 2012 | 1.56 | 1.723 | 18 | 1.47 | 1.246 | 15 | 1.7% | 0.06 [-0.63, 0.74] |
| Vijayakumar et al. 2011 | 1.27 | 0.59 | 10 | 1.23 | 0.67 | 10 | 1.5% | 0.06 [-0.82, 0.94] |
| Karthikbabu S. et al. 2011 | 1.27 | 0.59 | 15 | 1.2 | 0.68 | 15 | 1.6% | 0.11 [-0.61, 0.82] |
| Büyükavcı R et al. 2015 | 1.1 | 1.7126 | 32 | 0.8 | 1.2455 | 32 | 1.9% | 0.20 [-0.29, 0.69] |
| Verheyden G et al. 2009 | 0.53 | 0.87 | 17 | 0.06 | 1.42 | 16 | 1.7% | 0.39 [-0.30, 1.08] |
| Chan BKS 2015 (a) | 0.4 | 0.5 | 12 | 0.1 | 0.5 | 12 | 1.5% | 0.58 [-0.24, 1.40] |
| Chan BKS 2015 (b) | 0.4 | 0.5 | 13 | 0.1 | 0.5 | 12 | 1.5% | 0.58 [-0.22, 1.38] |
| **Subtotal (95% CI)** | | | **202** | | | **196** | **18.2%** | **0.13 [-0.07, 0.33]** |
| Heterogeneity: Tau² = 0.00; Chi² = 4.34, df = 10 (P = 0.93); I² = 0% | | | | | | | | |
| Test for overall effect: Z = 1.29 (P = 0.20) | | | | | | | | |
| **1.1.2 TIS DSB** | | | | | | | | |
| Büyükavcı R et al. 2015 | 3.7 | 5.7605 | 32 | 1.8 | 2.8024 | 32 | 1.9% | 0.41 [-0.08, 0.91] |
| Cabanas-Valdés et al. 2017 | 0.83 | 1.18 | 36 | 0.31 | 0.69 | 32 | 1.9% | 0.52 [0.04, 1.01] |
| An SH and Park SD 2017 | 1.27 | 1.49 | 15 | 0.29 | 0.47 | 14 | 1.6% | 0.85 [0.08, 1.61] |
| Cabanas-Valdés et al. 2015 | 4.1 | 2.8 | 40 | 1.82 | 1.73 | 39 | 1.9% | 0.97 [0.50, 1.43] |
| Jung KS et al. 2016 | 2.42 | 1.24 | 12 | 0.92 | 1.56 | 12 | 1.5% | 1.03 [0.17, 1.89] |
| Vijayakumar et al. 2011 | 4.07 | 1.22 | 10 | 2.8 | 0.98 | 10 | 1.4% | 1.10 [0.14, 2.05] |
| Verheyden G et al. 2009 | 3.47 | 1.81 | 17 | 1.25 | 2.02 | 16 | 1.6% | 1.13 [0.39, 1.87] |
| Karthikbabu S. et al. 2011 | 4.07 | 1.34 | 15 | 2.6 | 0.98 | 15 | 1.6% | 1.22 [0.43, 2.01] |
| Ahmed U et al. 2021 | 3.69 | 1.1017 | 42 | 1.93 | 1.1017 | 42 | 1.9% | 1.58 [1.09, 2.08] |
| Haruyama K et al. 2017 | 2.06 | 1.65 | 16 | 0.06 | 0.25 | 16 | 1.5% | 1.65 [0.84, 2.47] |
| Saeys W et al. 2012 | 4.39 | 1.195 | 18 | 1.33 | 1.397 | 15 | 1.4% | 2.31 [1.41, 3.22] |
| Chan BKS 2015 (a) | 2.9 | 1 | 12 | 0.3 | 0.8 | 12 | 1.2% | 2.77 [1.60, 3.95] |
| Chan BKS 2015 (b) | 2.8 | 0.9 | 13 | 0.3 | 0.8 | 12 | 1.2% | 2.83 [1.67, 3.99] |
| **Subtotal (95% CI)** | | | **278** | | | **267** | **20.5%** | **1.30 [0.94, 1.67]** |
| Heterogeneity: Tau² = 0.31; Chi² = 42.24, df = 12 (P < 0.0001); I² = 72% | | | | | | | | |
| Test for overall effect: Z = 6.94 (P < 0.00001) | | | | | | | | |
| **1.1.3 TIS COO** | | | | | | | | |
| Verheyden G et al. 2009 | 0.82 | 1.13 | 17 | 1.38 | 0.81 | 16 | 1.7% | -0.55 [-1.25, 0.14] |
| Cabanas-Valdés et al. 2015 | 0.85 | 0.7 | 40 | 0.66 | 0.86 | 39 | 1.9% | 0.24 [-0.20, 0.68] |
| Büyükavcı R et al. 2015 | 1.4 | 2.1796 | 32 | 0.7 | 1.0898 | 32 | 1.9% | 0.40 [-0.09, 0.90] |
| Cabanas-Valdés et al. 2017 | 0.42 | 0.77 | 36 | 0.15 | 0.37 | 32 | 1.9% | 0.43 [-0.05, 0.92] |
| Haruyama K et al. 2017 | 1.44 | 1.5 | 16 | 0.56 | 1.26 | 16 | 1.6% | 0.62 [-0.09, 1.33] |
| Jung KS et al. 2016 | 1.83 | 1.03 | 12 | 0.83 | 1.19 | 12 | 1.5% | 0.87 [0.02, 1.71] |
| Ahmed U et al. 2021 | 2.76 | 1.1017 | 42 | 1.74 | 1.1017 | 42 | 1.9% | 0.92 [0.47, 1.37] |
| An SH and Park SD 2017 | 0.8 | 0.67 | 15 | 0.21 | 0.43 | 14 | 1.6% | 1.01 [0.23, 1.79] |
| Chan BKS 2015 (b) | 1.5 | 0.5 | 13 | 0.5 | 0.5 | 12 | 1.4% | 1.93 [0.96, 2.91] |
| Saeys W et al. 2012 | 2.78 | 1.353 | 18 | 0.07 | 0.704 | 15 | 1.4% | 2.39 [1.47, 3.31] |
| Vijayakumar et al. 2011 | 2.23 | 0.31 | 10 | 1.17 | 0.51 | 10 | 1.2% | 2.41 [1.20, 3.61] |
| Karthikbabu S. et al. 2011 | 2.53 | 0.52 | 15 | 1.2 | 0.41 | 15 | 1.3% | 2.76 [1.73, 3.80] |
| Chan BKS 2015 (a) | 2.4 | 0.7 | 12 | 0.5 | 0.5 | 12 | 1.1% | 3.02 [1.79, 4.25] |
| **Subtotal (95% CI)** | | | **278** | | | **267** | **20.4%** | **1.14 [0.66, 1.63]** |
| Heterogeneity: Tau² = 0.62; Chi² = 75.68, df = 12 (P < 0.00001); I² = 84% | | | | | | | | |
| Test for overall effect: Z = 4.64 (P < 0.00001) | | | | | | | | |
| **1.1.4 TIS total** | | | | | | | | |
| Rose S and Vasanthan R 2016 | 1.83 | 1.59 | 12 | 1.75 | 1.96 | 12 | 1.6% | 0.04 [-0.76, 0.84] |
| Ko EJ et al. 2016 (a) | 7.1 | 8.362 | 10 | 4.7 | 5.5354 | 10 | 1.5% | 0.32 [-0.56, 1.21] |
| Büyükavcı R et al. 2015 | 5.9 | 9.1856 | 32 | 3.3 | 5.1377 | 32 | 1.9% | 0.35 [-0.15, 0.84] |
| Verheyden G et al. 2009 | 4.82 | 2.9 | 17 | 3.3 | 2.75 | 16 | 1.7% | 0.52 [-0.17, 1.22] |
| Bae SH et al. 2013 | 3.7 | 2.9905 | 8 | 1.8 | 2.1531 | 8 | 1.3% | 0.69 [-0.33, 1.71] |
| Cabanas-Valdés et al. 2017 | 1.25 | 1.25 | 36 | 0.47 | 0.84 | 32 | 1.9% | 0.72 [0.22, 1.21] |
| Yoo SD et al. 2010 | 4.78 | 3.99 | 28 | 2.45 | 2.11 | 31 | 1.8% | 0.73 [0.20, 1.26] |
| Park HK et al. 2018 | 3.07 | 2.7215 | 14 | 0.93 | 1.6185 | 15 | 1.6% | 0.94 [0.16, 1.71] |
| Jung KS et al. 2016 | 4.83 | 2.17 | 12 | 2.42 | 2.35 | 12 | 1.5% | 1.03 [0.17, 1.89] |
| An SH and Park SD 2017 | 2.27 | 1.75 | 15 | 0.71 | 0.73 | 14 | 1.6% | 1.12 [0.33, 1.91] |
| Jung KMM et al. 2021 | 5.66 | 2 | 12 | 3.56 | 1.5 | 12 | 1.5% | 1.15 [0.27, 2.02] |
| Cabanas-Valdés et al. 2015 | 5.88 | 3.48 | 40 | 2.48 | 2.2 | 39 | 1.9% | 1.15 [0.68, 1.63] |
| Kılınç M 2016 | 2.1 | 1.389 | 10 | 0.67 | 0.8716 | 9 | 1.4% | 1.16 [0.17, 2.15] |
| Ahmed U et al. 2021 | 7.74 | 2.2035 | 42 | 4.97 | 2.2035 | 42 | 1.9% | 1.25 [0.78, 1.71] |
| Karthikbabu S et al. 2022 (a) | 4.3 | 2.6727 | 28 | 0.6 | 2.6727 | 28 | 1.8% | 1.37 [0.78, 1.95] |
| Shin DC 2016 | 3.08 | 2.71 | 12 | 0.08 | 1.24 | 12 | 1.4% | 1.37 [0.47, 2.28] |
| Lee YW et al. 2012 | 3.7 | 2.3 | 14 | 0.9 | 1.4 | 14 | 1.5% | 1.43 [0.58, 2.27] |
| Haruyama K et al. 2017 | 4.13 | 2.31 | 16 | 1.19 | 1.42 | 16 | 1.6% | 1.49 [0.70, 2.29] |
| Karthikbabu S et al. 2022 (b) | 5 | 2.6727 | 28 | 0.6 | 2.6727 | 28 | 1.8% | 1.62 [1.01, 2.23] |
| Jung K 2014 | 2.33 | 1.5 | 9 | 0.13 | 0.83 | 8 | 1.2% | 1.69 [0.54, 2.85] |
| Yu SH and Park SD 2013 | 4 | 1.6329 | 7 | 0.5 | 1.5839 | 11 | 1.1% | 2.08 [0.86, 3.30] |
| Chan BKS 2015 (b) | 4.6 | 1.3 | 13 | 1.3 | 1.5 | 12 | 1.3% | 2.28 [1.24, 3.32] |
| Karthikbabu S. et al. 2011 | 7.93 | 1.28 | 15 | 4.87 | 1.25 | 15 | 1.4% | 2.35 [1.39, 3.31] |
| Saeys W et al. 2012 | 8.72 | 1.965 | 18 | 2.87 | 2.386 | 15 | 1.4% | 2.64 [1.67, 3.60] |
| Chan BKS 2015 (a) | 5.7 | 1.7 | 12 | 1.3 | 1.5 | 12 | 1.2% | 2.65 [1.50, 3.80] |
| Vijayakumar et al. 2011 | 6.96 | 1.28 | 10 | 3.13 | 1.24 | 10 | 1.0% | 2.91 [1.58, 4.25] |
| Mahmood W et al. 2022 | 4.5 | 1.43 | 20 | 1.05 | 0.49 | 21 | 1.4% | 3.20 [2.25, 4.15] |
| **Subtotal (95% CI)** | | | **490** | | | **486** | **40.9%** | **1.33 [1.06, 1.60]** |
| Heterogeneity: Tau² = 0.34; Chi² = 88.65, df = 26 (P < 0.00001); I² = 71% | | | | | | | | |
| Test for overall effect: Z = 9.57 (P < 0.00001) | | | | | | | | |
| **Total (95% CI)** | | | **1248** | | | **1216** | **100.0%** | **1.08 [0.89, 1.27]** |
| Heterogeneity: Tau² = 0.45; Chi² = 290.89, df = 63 (P < 0.00001); I² = 78% | | | | | | | | |
| Test for overall effect: Z = 11.00 (P < 0.00001) | | | | | | | | |

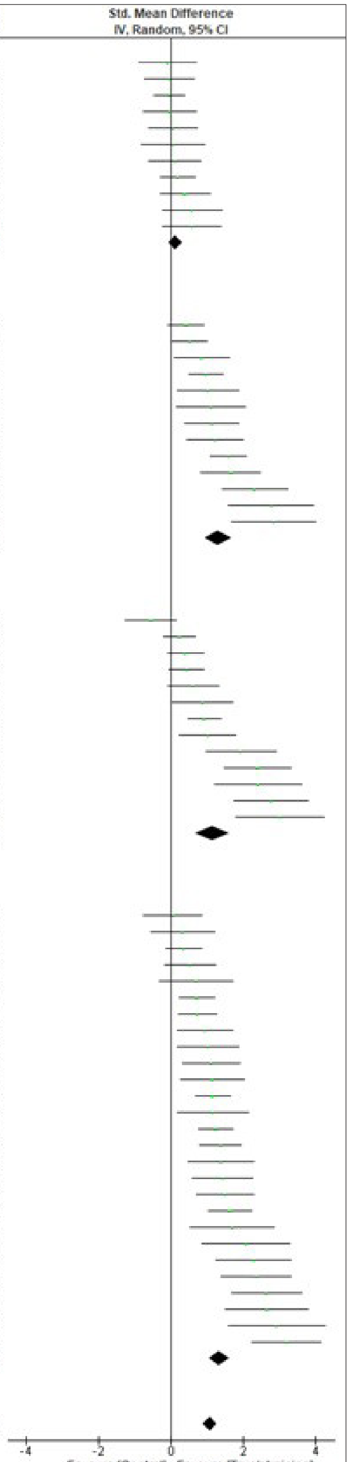


FIGURE 3: Forest plot for the effect of trunk training on trunk control measured by TIS

could be performed by the RevMan software on evidence quality for integration with judgements on the risk using bias assessment (Higgins & Thomas 2020). The analysis also aimed to demonstrate that these arbitrary or ambiguous judgements had no bearing on the outcomes of this systematic review and vice versa. Meanwhile,

4 compared SMD [95% CI] of the meta-analysis and sensitivity analysis. A funnel plot analysis was also carried out to check for any potential bias in publication (Sterne & Harbord 2004) (Figure 5). The influence of trunk training treatment intensities on the effect size was also examined using a meta-regression analysis with a random-effects model (Table 5). The mathematical equation for the "best fit" line to depict this meta-regression generated the relationship between the effect size and treatment intensity variables.

In generated meta-regressions, the regression coefficient explains how the effect size (or treatment effect) changes with a unit increase in the treatment intensity variables. The sign of the regression coefficient should also be taken into consideration. For a given increase in the treatment intensity variables, a negative sign for the coefficient indicated a reduction in the effect size. Alternatively, a positive sign corresponds to an increase in the effect size. The 2-sided *p*-value can assess the possibility of the relationship in both directions between the effect size and treatment intensity variables. Using the Comprehensive Meta-Analysis version 3 software trials, the funnel plot and

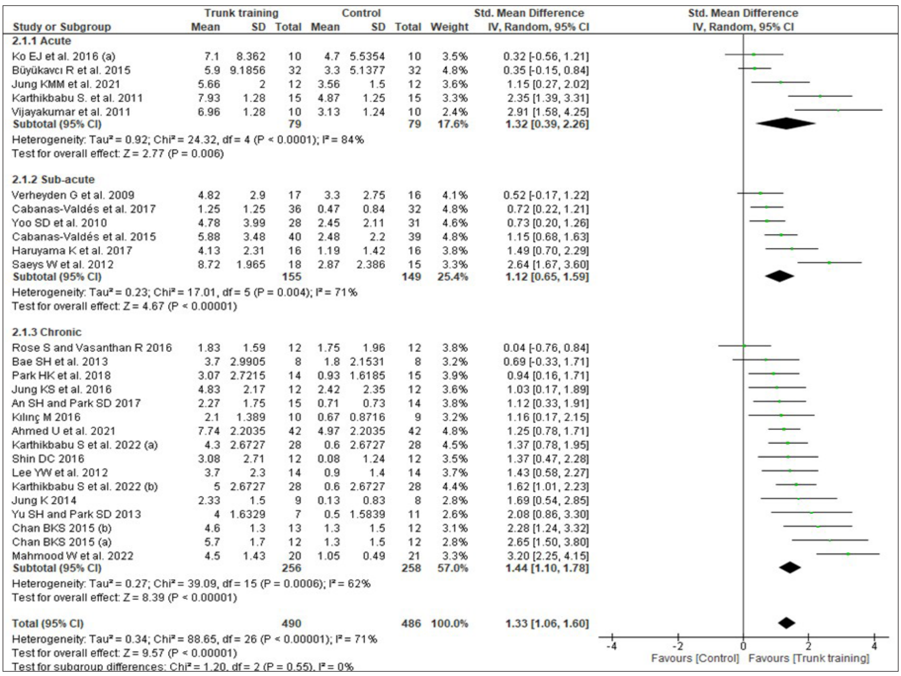


FIGURE 4: Forest plot for the effect of trunk training on trunk control at different stroke stages

TABLE 3: Summary of the forest plot for the effect of trunk training treatment intensities on trunk control

| The intensity of trunk training treatments | SMD [95% CI] | Heterogeneity [$I^2$] | Test for overall effect [Z] | Test for subgroup differences |
|---|---|---|---|---|
| Additional time to the conventional therapy | | | | |
| 15-min | 1.52 [0.90 – 2.14] | 82% | p < 0.00001 | |
| 20-min | 1.08 [0.35 – 1.80] | 53% | p = 0.004 | $Chi^2$ = 18.67, |
| 30-min | 1.23 [0.78 – 1.68] | 60% | p < 0.00001 | df = 5 |
| 45-min | 1.96 [0.34 – 3.57] | 81% | p = 0.02 | (p = 0.002), |
| 60-min | 2.35 [1.39 – 3.31] | NA | p < 0.00001 | $I^2$ = 73.2% |
| 120-min | 0.35 [-0.15 – 0.84] | NA | p = 0.17 | |
| **Total** | **1.34 [1.03 – 1.64]** | **72%** | **p < 0.00001** | |
| Session per week | | | | |
| 3 sessions | 1.08 [0.63 – 1.52] | 53% | p < 0.00001 | $Chi^2$ = 7.09, |
| 4 sessions | 1.80 [0.39 – 3.22] | 87% | p = 0.01 | df = 3 |
| 5 sessions | 1.35 [1.03 – 1.67] | 66% | p < 0.00001 | (p = 0.07), |
| 6 sessions | 2.91 [1.58 – 4.25] | NA | p < 0.0001 | $I^2$ = 57.7% |
| **Total** | **1.38 [1.11 – 1.65]** | **69%** | **p < 0.00001** | |
| Weeks of treatment administered | | | | |
| 3 weeks | 1.32 [0.39 – 2.26] | 84% | p = 0.006 | |
| 4 weeks | 1.07 [0.71 – 1.42] | 39% | p < 0.00001 | $Chi^2$ = 34.09, |
| 5 weeks | 0.85 [0.49 – 1.21] | 25% | p < 0.00001 | df = 5 |
| 6 weeks | 1.71 [1.30 – 2.12] | 27% | p < 0.00001 | (p < 0.00001), |
| 8 weeks | 2.92 [2.24 – 3.60] | 0% | p < 0.00001 | $I^2$ = 85.3% |
| 12 weeks | 1.15 [0.76 – 1.54] | 0% | p < 0.00001 | |
| **Total** | **1.33 [1.06 – 1.60]** | **71%** | **p < 0.00001** | |
| Complexity alteration of delivered treatment | | | | |
| Unstable Surfaces | 1.46 [1.06 – 1.85] | 29% | p < 0.00001 | |
| Core Stability Exercise | 1.64 [0.88 – 2.39] | 82% | p < 0.0001 | $Chi^2$ = 9.08, |
| Core Strengthening Program | 0.46 [-0.21 – 1.12] | 49% | p = 0.18 | df = 4 |
| Electrical Stimulation | 1.46 [-0.82 – 3.74] | 90% | p = 0.21 | (p = 0.06), |
| Others | 0.98 [0.60 – 1.35] | 41% | p < 0.00001 | $I^2$ = 55.9% |
| **Total** | **1.23 [0.94 – 1.52]** | **69%** | **p < 0.00001** | |
| Variation types of delivered treatments | | | | |
| **Total** | **1.40 [0.94 – 1.87]** | **62%** | **p < 0.00001** | |

meta-regression analysis were also carried out (Borenstein et al. 2013). The SMD value was classified into four categories: 0-0.19 (no effects), 0.20-0.49 (small effect), 0.50-0.79 (moderate effect), and 0.80 (large effect) (Cohen 1988).

## RESULTS

### Study Selection Characteristics

In this study, 25 out of the 2454 studies that were retrieved from all databases were taken into account. The search strategy was presented in the PRISMA flowchart (Figure 1). The characteristics of the subjects who were involved in the trunk training experiments are listed in Table 2. Out of the total 976

TABLE 4: Standardized mean difference (SMD) of the meta-analysis versus sensitivity analysis in studies with good methodological quality

| Study outcome | SMD [95% CI] | |
|---|---|---|
| | Meta-analysis | Sensitivity analysis |
| 1. Trunk control | | |
| TIS SSB | 0.13 [-0.07 – 0.33] | 0.20 [-0.03 – 0.43] |
| TIS DSB | 1.30 [0.94 – 1.67] | 1.31 [0.88 – 1.74] |
| TIS COO | 1.14 [0.66 – 1.63] | 1.22 [0.63 – 1.81] |
| TIS total | 1.33 [1.06 – 1.60] | 1.50 [1.14 – 1.86] |
| **Total** | **1.08 [0.89 – 1.27]** | **1.16 [0.93 – 1.39]** |
| 2. Stroke severity | | |
| Acute | 1.32 [0.39 – 2.26] | 1.60 [0.43 – 2.77] |
| Sub-acute | 1.12 [0.65 – 1.59] | 1.22 [0.65 – 1.80] |
| Chronic | 1.44 [1.10 – 1.78] | 1.64 [1.15 – 2.12] |
| **Total** | **1.33 [1.06 – 1.60]** | **1.50 [1.14 – 1.86]** |
| 3. Intensity | | |
| Additional time to the convention therapy | | |
| 15 min | 1.52 [0.90 – 2.14] | 1.52 [0.90 – 2.14] |
| 20 min | 1.08 [0.35 – 1.80] | 1.44 [0.84 – 2.04] |
| 30 min | 1.23 [0.78 – 1.68] | 1.43 [0.69 – 2.18] |
| 45 min | 1.96 [0.34 – 3.57] | 2.91 [1.58 – 4.25] |
| 60 min | 2.35 [1.39 – 3.31] | 2.35 [1.39 – 3.31] |
| 120 min | 0.35 [-0.15 – 0.84] | 0.35 [-0.15 – 0.84] |
| **Total** | **1.34 [1.03 – 1.64]** | **1.50 [1.11 – 1.90]** |
| Session per week | | |
| 3 sessions | 1.08 [0.63, 1.52] | 1.44 [1.05, 1.83] |
| 4 sessions | 1.80 [0.39, 3.22] | 1.80 [0.39, 3.22] |
| 5 sessions | 1.35 [1.03, 1.67] | 1.51 [1.05, 1.97] |
| 6 sessions | 2.91 [1.58, 4.25] | 2.91 [1.58, 4.25] |
| **Total** | **1.38 [1.11, 1.65]** | **1.58 [1.22, 1.93]** |
| Weeks of treatment administered | | |
| 3 weeks | 1.32 [0.39, 2.26] | 1.60 [0.43, 2.77] |
| 4 weeks | 1.07 [0.71, 1.42] | 1.23 [0.66, 1.80] |
| 5 weeks | 0.85 [0.49, 1.21] | 0.85 [0.49, 1.21] |
| 6 weeks | 1.71 [1.30, 2.12] | 1.81 [1.29, 2.32] |
| 8 weeks | 2.92 [2.24, 3.60] | 2.92 [2.24, 3.60] |
| 12 weeks | 1.15 [0.76, 1.54] | 1.16 [0.17, 2.15] |
| **Total** | **1.33 [1.06, 1.60]** | **1.50 [1.14, 1.86]** |
| Complexity alteration of delivered treatment | | |
| Unstable surfaces | 1.46 [1.06 – 1.85] | 1.64 [1.27 – 2.00] |
| Core Stability Exercise | 1.64 [0.88 – 2.39] | 1.64 [0.88 – 2.39] |
| Core Strengthening Program | 0.46 [-0.21 – 1.12] | 0.04 [-0.76 – 0.84] |
| Electrical stimulation | 1.46 [-0.82 – 3.74] | 2.65 [1.50 – 3.80] |
| Others | 0.98 [0.60 – 1.35] | 0.91 [0.35 – 1.46] |
| **Total** | **1.23 [0.94 – 1.52]** | **1.42 [1.02 – 1.81]** |
| Variation types of delivered treatments | | |
| **Total** | **1.40 [0.94 – 1.87]** | **1.81 [1.29 – 2.32]** |

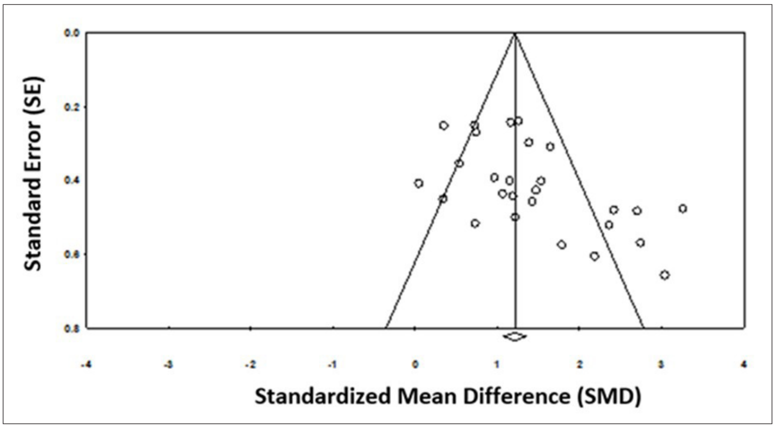


FIGURE 5: Funnel plots for publication bias in the included trunk training studies

stroke participants from the 25 trials that were included, 158 (16%) were acute, 304 (31%) were sub-acute, and 514 (53%) were chronic patients. Based on the 25 studies that examine the treatment intensity, the variables were categorised as follows; (i) additional time to the conventional therapy; (ii) more sessions per week; (iii) more weeks of treatment were administered; (iv) complexity alteration of delivered treatment; and (v) variation types of delivered treatment.

All participants were either inpatients or outpatients who were over the age of 18. The amount of time dedicated to trunk training and traditional therapy ranged from 15

TABLE 5: Summary of the main results for the meta-regression of the effect of trunk training treatment intensities on the effect sizes

| Covariate & Variables | Coefficient | Standard Error | 95% Lower | 95% Upper | Z-value | 2-sided p-value | |
|---|---|---|---|---|---|---|---|
| Intercept | 1.79 | 0.32 | 1.17 | 2.41 | 5.68 | 0 | |
| Additional time | -0.01 | 0.01 | -0.02 | 0.01 | -1.02 | 0.310 | |
| Intercept | 0.96 | 1.10 | -1.19 | 3.12 | 0.88 | 0.381 | |
| No. of session | 0.15 | 0.24 | -0.32 | 0.62 | 0.63 | 0.531 | |
| Intercept | 1.03 | 0.48 | 0.08 | 1.98 | 2.13 | 0.034 | |
| No. of total weeks | 0.10 | 0.09 | -0.07 | 0.27 | 1.17 | 0.242 | |
| Intercept | 1.93 | 0.34 | 1.26 | 2.61 | 5.64 | 0 | |
| Altering complexity: CSE | -0.27 | 0.49 | -1.24 | 0.70 | -0.54 | 0.586 | |
| Altering complexity: CSP | -1.89 | 0.87 | -3.60 | -0.18 | -2.17 | 0.030 | |
| Altering complexity: ES | 0.81 | 0.96 | -1.07 | 2.69 | 0.85 | 0.398 | p=0.129 |
| Altering complexity: Others | -0.94 | 0.53 | -1.97 | 0.10 | -1.77 | 0.077 | |
| Altering complexity: US | -0.35 | 0.57 | -1.47 | 0.77 | -0.61 | 0.542 | |

CSE: Core stability exercise; CSP: Core/trunk strengthening program; ES: Electrical stimulation; US: Unstable support surfaces to 120 minutes. There were between three and six trunk training sessions per week. Meanwhile, the time required to complete trunk training varied from three to twelve weeks. A few of the included intervention protocols in changing the treatment complexity used other unstable support surfaces, core stability exercises, strengthening the trunk or core programme, functional electrical stimulation, a programme for both land-based and aquatic therapy, and a programme for Bobath-based therapy. In this study, the trunk neuromuscular electrical stimulation (tNMES), transcutaneous electrical nerve stimulation (TENS), and high-intensity multiplanar trunk training coupled with dual-task (HIMTD) were the intervention protocols used in varying the types of treatment components (Table 2).

The characteristics of the study population, including baseline demographics, stroke stages, treatment intensity and other relevant factors were transparently reported. This action helped to understand the extent of heterogeneity and facilitates meta-analyses and meta-regression to further explore treatment effects across different stroke populations.

## Risk of Bias Assessment

Figure 2 illustrated the methodological quality evaluation and bias risk based on the recommendations in the Cochrane Handbook (Higgins & Thomas 2020). Due to a lack of justification in their statement and the difficulty of blinding participants and personnel to group assignments in exercise intervention protocols, 18 out of 25 studies were categorised as an unclear-risk score for the category "blinding of participants and personnel" (Higgins & Thomas 2020). This assumption suggested a plausible bias that imposed some doubt on the findings. Including trial results with a high-risk score in a meta-analysis could result in less reliable evidence than if such trials were excluded (Higgins & Thomas 2020). It was determined that the reliability of the included studies was insufficient to be methodologically sound. Further details on this effect were discussed in the methodological quality and sensitivity analysis section.

## Methodological Quality of the Included Studies

The funnel plot of standard error (SE) against SMD to evaluate publication bias from the studies of trunk training was depicted in Figure 5. Additionally, the plot indicated an asymmetrical distribution, as publication bias cannot be completely ruled out. This observation could be introduced by the severely constrained access to acute patients. Simultaneously, the control groups experienced a variety of treatment protocols (conventional therapy, standard care therapy, placebo, and sham treatment). Thus, this lack of stratification produced a substantial bias based on ethical and practical considerations.

Further analysis revealed small-study effects skewed toward larger SMD (Chan et al. 2015; Jung et al. 2014; Karthikbabu 2011; Mahmood et al. 2022; Saeys et al. 2012;

Vijayakumar et al. 2011; Yu & Park 2013) (Figure 5). Due to a lack of clarification about the blinding of the participants and personnel (which was difficult concerning treatment), these studies acquired an unclear-risk score. Alternatively, the publication bias received a high-risk score for the study of Yu & Park (2013), resulting biases reporting and a lack of data on four of the seven domains. This discovery suggested that the SMD differed according to study size, which could lead to the source of asymmetry in funnel plots. One study produced an SMD of 0.04 (Rose & Vasanthan 2016), which was accounted for the lack of clarity on the blinding of participants and personnel and selective reporting. Overall, the funnel plot of trunk training studies revealed a middle asymmetrical funnel shape, as small study sizes with low SMD were missing.

**Meta-analysis**

In reporting the results of the meta-analysis, the terms acute, sub-acute and chronic were used to address the stroke stages. Meanwhile, small, medium and large were used to standardise the treatment effectiveness of the studies which in this case was trunk training for stroke rehabilitation.

According to the meta-analysis of all included studies, the trunk training treatment intensities for trunk control among stroke patients produced a significant effect size. In Figure 3, a forest plot for the effect of trunk training on trunk control using the TIS score revealed a large and significant effect with SMD of 1.08 [(95% CI: 0.89-1.2); $p<0.00001$; $I^2 = 78\%$] and a high heterogeneity ($I^2 = 78\%$). The test for subgroup differences indicated a statistically significant subgroup effect ($p<0.00001$). This demonstrated that, in comparison to the control group, the TIS subscales considerably modified the impact of trunk training. All of the TIS subscales favored trunk training over the control group, even though the treatment impact was larger for the dynamic sitting balance subscale (TIS DSB), trunk coordination subscale (TIS COO), and the TIS total compared to the static sitting balance subscale (TIS SSB). The subgroup effect was quantitative, while the heterogeneity for subgroup differences was high ($I^2 = 95\%$).

Figure 4 presented a forest plot to show how trunk training affects trunk control at different stages of stroke. A large and significant effect was presented in the present meta-analysis, which favored the trunk training group with 1.33 [(95% CI: 1.06-1.60); $p<0.00001$; $I^2 = 71\%$] for trunk control at different stroke stages using the TIS. This finding shows that trunk training was an effective rehabilitation for acute, sub-acute and chronic stroke populations. Also, the choice of trunk control as the standard outcome measure and the TIS as the sole assessments tools had enhanced the ability to capture and compare treatment effects accurately for each stroke stage (e.g. acute, sub-acute and chronic). Following the TIS score, the trunk training impact on trunk control was not significantly changed by stroke stages, according to the test for subgroup differences ($p = 0.55$; no significant subgroup effect was found). The acute and sub-acute subgroups had fewer trials and individuals, which made it to be insufficient to identify subgroup differences. Interestingly, the pooled effect estimated for the acute, sub-acute, and chronic subgroups favouring trunk training were noted. Hence, the subgroup effect was quantitative.

The data in Table 3 (forest plot not presented), showed how the intensity of trunk training treatments affects trunk control. The overall treatment effect shows that trunk training has a large and significant effect on trunk control, with SMD>1.0 for each treatment intensity variables. The heterogeneity results were significant, ranging from 62 to 72%. Subgroup differences in treatment intensity variables showed a statistically significant subgroup effect with a *p*-value of less than 0.1 (Table 3). These findings described that the complexity alteration of the treatment being delivered, the increase in sessions per week and the number of total weeks, and the time addition to conventional therapy all significantly impacted the effectiveness of the trunk training group measured by the TIS score. Nonetheless, no subgroup differences test was conducted for varying the types of treatment using the TIS score. This absence resulted from smaller number of trials and participants contributing data to the treatment intensity variable.

Due to methodological issues in numerous studies, a sensitivity analysis was carried out, and a meta-regression analysis was done to ascertain how trunk training treatment intensities affected trunk control by analysing the SMD range.

## Sensitivity Analysis

In Table 4 (forest plot not presented), the SMD was used in the sensitivity analysis to determine the impact of trunk training on trunk control, and the findings showed significant impacts (SMD = 1.16 [95% CI: 0.93-1.39]) in favour of trunk training. The treatment effect at different stroke stages measured by the TIS score also revealed a significantly large effect size (SMD = 1.50 [95% CI: 1.14-1.86]). The heterogeneity for both results was high ($I^2$ = 80% and 76%), while substantial heterogeneity existed ($I^2$ = 50% to 90%) between the trials regarding the efficacy of trunk training treatment intensities on trunk control using the TIS score. The validity of the treatment effect estimates for trunk control was nonetheless confirmed by the *p*-value from the $Chi^2$ test. This validation was observed when the time was added to conventional therapy, the frequency of sessions per week and the number of treatment weeks overall were respectively increased, the complexity of the treatment was changed, and different types of treatment were delivered. The *p*-value for each treatment intensity was less than 0.1, demonstrating that heterogeneity and not sampling error were to blame for the variation in effect estimates (Higgins & Thomas 2020).

Interestingly, the risk of bias assessment discovered that weak studies (high-risk scores) tend to suppress SMD in comparison to stronger studies (low- and unclear-risk scores) (Ahmed et al. 2021; Bae et al. 2013; Jung et al. 2016; Ko et al. 2016; Lee et al. 2012; Park et al. 2019; Yoo et al. 2010). Based on more robust studies, the SMD was slightly larger in favour of trunk training (see Table 4). After adjusting for study quality, this result did not alter the direction of effects. Therefore, the result supported the claim that trunk training could elicit superior effects than the control condition.

## Meta-regression Analysis

Table 5 represented the meta-regression results of the impact of trunk training treatment intensities on the effect sizes of trunk control measured using the TIS score. The analysis was performed across 18 studies, excluding trials with a high-risk bias score. The effect size index was the SMD, while the random-effects model and 2-sided p-value were used to analyse the results. The studies included in the investigation were meant to be a random selection from a universe of prospective research. The results were then used to reach the conclusion of that universe (Borenstein et al. 2013). According to Table 5, trunk training results in SMD increased by 14.93% and 10.22% (for every 1-unit increase in the number of sessions and total weeks). The numerical data also suggested that practising trunk exercises for an additional minute on top of conventional therapy reduced SMD by 0.74%. There was no evidence of a relationship between SMD and changing the complexity of the treatment delivered in any data groups (CSE, CSP, ES, Others, and US).

Apart from the electrical stimulation (ES) group, the trunk training results revealed that SMD decreased as the complexity of the treatment increased. This finding suggested that the treatment effect of trunk training could diminish when the complexity of the delivered treatment was altered. Nonetheless, the electrical stimulation group acquired fewer studies, thus necessitating further research. As fewer than 10 studies were in a meta-analysis, it was impossible to rule out the possibility that different treatment types were used in the regression analysis (Higgins & Thomas 2020).

# DISCUSSION

This research investigated the efficacy of various treatment intensity variables in trunk training protocols for stroke patients. The study encompassed 25 randomised controlled trials (RCTs) involving a total of 976 participants. Among these trials, five focused on acute stroke patients, six on sub-acute stroke patients, and 14 on chronic stroke patients. The study compared the effectiveness of trunk training protocols with different treatment intensity.

Trunk exercise durations of 13.5 hours for acute stroke patients and 16 hours for sub-acute stroke patients were found to enhance trunk control. On the other hand, chronic stroke patients showed meaningful improvements in effect sizes with 10 hours of core stability exercises during treatment. The most favourable outcomes in restoring trunk control for stroke patients were observed with trunk training using core stability exercise protocols lasting 15 minutes, at least five times per week, for eight weeks of intervention, compared to the 40-minute duration of conventional therapy. This approach yielded larger effect sizes (SMD = 3.20 [95% CI: 2.25-4.15]) due to more trials and a greater number of participants contributing data from chronic stroke patients compared to acute and sub-acute stroke patients.

The meta-analysis findings from this study indicated that trunk exercise had the potential to improve trunk control in both the acute and sub-acute stages of stroke. Similarly, Alhwoaimel et al. (2019) noted that most studies examining trunk exercise significantly improved trunk performance. Furthermore, Cabanas-Valdes et al. (2013) and Van Criekingie et al. (2019) reported significant trunk control improvement in their systematic reviews of stroke patients practising trunk exercises using unstable support surfaces. Nonetheless, Alhwoaimel et al. (2019) discovered that trunk exercise significantly improved trunk performance for chronic stroke patients. Surprisingly, these findings were not following this study as core stability exercises significantly increased the effect size and improved trunk performances following chronic stroke patients.

Core stability exercise in the chronic phase of stroke allows for continued muscle strength development and enhances functions related to stability of the vertebral column, pelvis, lumbar, and hip regions (Kim et al. 2015). Maintaining spine stability is crucial for static and dynamic balance, as well as postural adjustment, to prevent spine buckling in response to perturbations (Cabanas-Valdés et al. 2016; Yu & Park 2013). Co-contraction of the transversus abdominis and multifidus muscles plays a role in spine improvement. A recent systematic review found that trunk training effectively restored symmetry in transversus abdominal muscle thickness and improved muscle activity in the internal oblique abdominis, resulting in increased spine and trunk stability. However, further detailed follow-up studies are needed to explore the long-term effects of core stability exercise and conventional therapy. Only one follow-up study conducted three months after intervention, provided support for these claims, demonstrating that core stability exercise and conventional physiotherapy had a positive impact on dynamic sitting and standing balance as well as gait in post-stroke patients (Cabanas-Valdés et al. 2017).

Trunk training treatment intensities demonstrated large treatment effects (SMD = 1.08-1.40) on trunk control among stroke patients compared to control group conditions. However, it is important to consider potential bias favoring trunk training due to methodological issues. Notably, a follow-up sensitivity analysis conducted in this study, which included only strong methodological studies while excluding high-risk score studies, resulted in a higher effect size (SMD = 1.16-1.81) (Table 4). This follow-up analysis revealed that effect sizes significantly increased in favour of trunk training when considering only studies with strong methodological quality.

Practicing trunk training with different treatment intensities has shown benefits, considering that patients have varying preferences and respond differently to behavioural changes and fatigue complaints (Zedlitz et al. 2011). For instance, engaging in one additional hour of trunk training for four days per week over four weeks led to improved mobility. Trunk performance can be influenced by the intensity of trunk training, with frequencies of at least five sessions per week, lasting 15 to 120 minutes each, producing significant improvements within 3 to 12 weeks. Longer-term interventions, lasting 12 weeks, were found to be necessary for reducing the severity of motor impairments (Vijayakumar et al. 2011). However, it is important to note that higher treatment intensities may result in more individuals withdrawing from both the experimental and control groups due to fatigue complaints. Drop-out rates tended to be higher among older individuals, particularly those over 70 years old. While the treatment intensity was effective, further research is needed to determine its suitability for the treatment of older populations (Van Criekinge et al. 2020).

The meta-regression analysis conducted in this study did not find a significant correlation ($p>0.05$) between the intensity of trunk training treatments and the effect sizes. This suggests that the effect sizes were independent of the intensity of trunk training. Consequently, frequencies of at least five sessions per week, lasting 15 minutes each, over eight weeks of intervention were found to be sufficient for significantly improving trunk control in stroke patients. Additionally, specific trunk exercises and standard physiotherapy treatments had shown to enhance trunk function in the early stages of stroke (Saeys et al. 2012; Vijayakumar et al. 2011). Clinical observations had shown that individuals with chronic stroke had difficulty retraining lower trunk side flexion and rotation motions.

Patients who received balance training (core stability exercise) and trunk-specific training in addition to traditional physical therapy portrayed greater improvement than those who received only traditional care (Mahmood et al. 2022). These protocols demonstrated that trunk training had little effect on trunk control. Therefore, additional standard physiotherapy or conventional physical therapy was required. Alternatively, previous study acknowledged that most protocols of the included studies were different concerning types of exercises and treatment intensity (Van Criekinge et al. 2019). Unfortunately, this study did not compute meta-regression in their investigation, whose outcomes were difficult for comparison.

In summary, incorporating core stability exercise for chronic stroke patients, with an additional 15 minutes to the conventional therapy of 40 minutes, had been shown to improve trunk control performance (Mahmood et al. 2022). However, trunk exercises are more suitable for acute and sub-acute stroke patients. These exercises involve selective movements of the upper and lower limbs in supine and sitting positions, providing a safe and effective treatment approach for the acute and sub-acute populations. Longer treatment periods ranging from 13.5-16 hours are needed to achieve a significant impact on treatment effectiveness (Saeys et al. 2012; Vijayakumar et al. 2011). In general, shorter treatment durations with higher intensity are recommended to enhance trunk control performance in chronic stroke patients, while lower treatment intensity with longer durations is suggested for acute and sub-acute stroke patients.

This meta-analytical review followed the PRISMA guideline (Page et al. 2021) and employed the PICOS approach (Liberati et al. 2009). The overall sample size of 976 participants across 25 included trials was considered substantial, making it one of the largest meta-analyses investigating the effects of trunk training treatment intensities on trunk control in stroke patients. Sensitivity analysis was conducted to account for differences in study quality, and the risk score and methodological quality were deemed to be high quality. However, the overall study quality (ROB score) remained unclear for all trunk training trials. The included studies exhibited significant heterogeneity, and the confidence intervals of the computed effect sizes were relatively narrow (refer to Figure 3, 4 & Table 3). Despite these challenges, the study results provided a comprehensive understanding of the diverse effects of trunk training in stroke rehabilitation.

According to the stroke severity in the underlying studies, a lack of patient stratification could provoke a selection bias. This bias could occur as acute and sub-acute patients were less prone to physical exercise than chronic patients. Additionally, certain studies did not include the diagnostic stroke scale. The heterogeneity of the intervention limited the treatment intensity variables. As a result, it was impossible to calculate subgroup analyses of stroke severity and treatment intensity. The meta-analysis was performed using the data evaluated by the TIS score to study the impact of trunk training treatment intensities on the recovery of trunk motor impairment after stroke to address these issues.

Due to the inclusion of the weaker studies in the meta-regression analysis, the results in this study regarding the influence of various treatment intensity variables could be skewed and could yield different results. Additionally, the transformation to characterise groups to enable adequate comparison and the various treatment intensity descriptions in the trials could limit the meta-regression analysis. Moreover, trunk training makes it impossible to blind the therapist, subject, and assessor, which could introduce bias. Numerous studies also contrasted various forms of treatment delivery with just trunk training without a control group. There was a sizable bias due to the different protocols used by the control groups and the absence of stratification.

The overall risk of bias in this systematic review was high which raised questions regarding the strength of data supporting the usefulness of trunk training treatment intensities on trunk control in stroke patients. Systematic reviews are critical in assisting healthcare practitioners and policymakers in making sound decisions. However, the high risk of bias in this review compromised the confidence in the efficacy of these interventions, which may create uncertainty in their implementation in clinical practice. Given the limitations posed by the high risk of bias, it was crucial to interpret the study's conclusion with caution. Future research should acknowledge the limitations and the potential impact of bias on the results. Further high-quality studies with rigorous methodology and low risk of bias are needed to provide more reliable evidence on the efficacy of trunk training treatment intensities for improving trunk control in stroke patients.

## CONCLUSION

In general the meta-analysis demonstrated that trunk training was an effective complementary treatment option for stroke patients. When only stronger studies were considered, the overall treatment effects of trunk training revealed larger effect sizes. Based on scientific evidence towards the improvement of trunk control, this finding underpinned the need to allocate stroke patients to specific trunk training. Hence, a novel approach of adding 15 minutess of core stability exercise to 40 minutess of conventional therapy (five sessions per week over eight weeks) should be gradually integrated into the treatment protocol of chronic stroke patients.

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