KU LEUVEN

GROEP BIOMEDISCHE WETENSCHAPPEN

FACULTEIT BEWEGINGS- EN REVALIDATIEWETENSCHAPPEN

Trunk rehabilitation in the different recovery phases post-stroke: a systematic review and meta-analysis

Door Anne Lubbe
en Stijn Denissen

masterproef aangeboden tot het behalen van de graad van Master of Science in de revalidatiewetenschappen en kinesitherapie

o.l.v.
Prof. dr. G. Verheyden, promotor
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Woord Vooraf

Wij betuigen allereerst graag onze dank aan onze promotor, Prof. G. Verheyden, die gedurende het schrijven van de masterproef altijd bereid stond te hulp te schieten door middel van zowel snel en efficiënt mailcontact, als persoonlijke gesprekken om verduidelijking te bieden in de deelaspecten van het totale proces. Door middel van zijn inzet, heldere feedback en aanmoediging kunnen wij met trots het werk aanbieden waar wij de afgelopen twee academiejaren hard aan hebben gewerkt.
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Bibliotheek 2 Bergen en in het bijzonder Marleen Michels kaderen ook in onze dankbetuiging wegens hun bijdrage aan het opstellen van de zoekstrategieën voor de medische databases en de uitleg over de werking van Mendeley, dat van aanzienlijk belang was bij de ordening van de enorme hoeveelheid potentiële studies.
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Haaren, 9 januari 2018 S.D.

’s-Graveland, 9 januari 2018 A.L.

Situering

Wereldwijd is het cerebrovasculair accident (CVA), ischemisch of hemorragisch, een belangrijke oorzaak voor een grote financiële maatschappelijke belasting. Deze neurologische stoornis is momenteel reeds een frequent gezien probleem. Gezien de stijgende inactiviteit en inname van voedsel met hogere zoutwaarden, vetten en suikers dreigt het aantal personen dat jaarlijks een CVA krijgt in de toekomst zelfs verder te stijgen.[1] Niet enkel voor de maatschappij is de last hoog. Het individu zelf ondervindt problemen op vlak van verminderde functionele activiteiten, zelfzorg, seksualiteit, sociaal contact en algemene zelfstandigheid. Dit heeft op zijn beurt ook weer impact op de directe omgeving van de patiënt, waardoor een CVA dus gevolgen heeft op persoonlijk, familiaal en maatschappelijk vlak.

Het probleem van functieverlies in de romp door verminderde mogelijkheid tot aanspreken van rompmusculatuur draagt bij aan deze problematieken door middel van zijn impact op onder andere gang, mobiliteit, statische en dynamische (zit-)balans en functionele activiteiten.[2-5] In het afgelopen decennium werd reeds veel gepubliceerd met betrekking tot het aanpakken van deze rompproblematiek. Zo werd er voornamelijk toegespitst op aard en kwantiteit van romprevalidatie. CVA wordt echter onderverdeeld in 5 herstelfasen[6], en tot op heden werd niet gerapporteerd over de effectiviteit van de verschillende rompstrategieën in deze verschillende fasen. Met andere woorden: wat kunnen we wanneer doen om de meeste vooruitgang in rompfunctie te bekomen. Bijkomend zijn sinds de laatste review over de effectiviteit van de verschillende romprevalidatie-protocollen op rompfunctie veel studies gerapporteerd die ook andere strategieën aanwenden om rompproblematiek aan te pakken.

Deze review geeft daarom een actueel overzicht over de effectiviteit van deze verschillende strategieën en bekijkt bijkomend welke effecten ze hebben in de verschillende herstelfasen na CVA. Hiermee draagt het bij aan de kennis van de neurologische kinesitherapeut om de juiste therapie op het juiste moment bij de patiënt aan te wenden, en zo eerdergenoemde individuele en maatschappelijke problematieken te kunnen helpen oplossen.

De CVA-groep binnen de onderzoekseenheid Neuromotorische Revalidatie onder leiding van Prof. G. Verheyden doet reeds gedurende meerdere jaren onderzoek naar het probleem van rompproblematiek bij CVA-patiënten. Zo werden onder andere het verloop van herstel van de romp na een CVA bestudeerd[7], en de predictieve waarde van rompfunctie op het functioneel herstel post-CVA[8]. Verder werd door deze groep gerapporteerd over het kwantificeren en specifiëren van rompproblematiek. Dit werd gedaan in de vorm van het ontwikkelen van een specifiek meetinstrument (Trunk Impairment Scale (TIS)) dat momenteel wereldwijd gebruikt wordt[9], alsook het vaststellen van de beste manier waarop rompproblematiek getest kan worden door middel van een systematische review[10]. Internationale bijdragen werden door deze onderzoekseenheid ook gedaan om niet-Engelstalige versies van de TIS te helpen valideren, zoals een Italiaanse[11] en Noorse[12] versie van de TIS. Dit onderzoeksproject kadert in het behandelingsaspect van de rompproblematiek. Eerder publiceerden ze reeds over het effect van additionele therapie op rompprestatie post-CVA, waarbij zij vonden dat romptraining gericht op het verbeteren van zitbalans en selectieve rompbewegingen effectief blijken in het verbeteren van dynamische rompfunctie post-CVA[13]. Deze systematische review werd eveneens onder leiding Prof. dr. G. Verheyden opgesteld om meer definitieve conclusies te kunnen aanbieden over de effecten van romprevalidatie in de revalidatie van CVA, meer specifiek welk protocol het meest effectief is in de verschillende herstelfasen post-CVA.

Deze review leverde informatie op over het effect van romprevalidatie op verschillende soorten uitkomstparameters; rompfunctie, balans, gang, mobiliteit en functionaliteit. Deze masterproef focust enkel op de parameters gelinkt aan rompfunctie. Een andere masterproef zal de resultaten presenteren van de andere parameters.

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Trunk rehabilitation in the different recovery phases post-stroke: a systematic review and meta-analysis

Abstract

Background: Therapists' toolbox is increasing steadily regarding interventions to treat trunk impairment, a frequently observed complication with major impact on functional activities in post-stroke patients. *Objective:* To investigate the effect of different trunk rehabilitation modalities on trunk performance in different recovery phases post-stroke. *Data sources:* Five databases; MEDLINE (Pubmed), EMBASE, CINAHL, CENTRAL (Cochrane) and PEDro were searched for studies meeting inclusion criteria from November 2012 up to October 2017. Furthermore, included studies in four prior systematic reviews investigating trunk rehabilitation post-stroke were searched for studies published before November 2012. *Study selection:* Randomized controlled trials in English, Dutch, French or German assessing trunk rehabilitation in sitting or supine in all phases post- stroke. Seven different rehabilitation protocols were defined.

Results: Our search yielded 26 trials, of which 7 were excluded from meta-analysis due to missing data. Forest plots of all 7 protocols were made investigating 3 phases post-stroke; namely early subacute, late subacute and chronic phase. In the early subacute phase, the greatest effect on trunk performance resulted from the sitting reaching protocol (SMD=3.81;95%CI:1.63,5.98), in the late subacute phase weight-shift training yielded the greatest effect (SMD=1.77;95%CI:1.11,2.44) and selective trunk exercises showed the largest effects on trunk performance in the chronic phase post-stroke (SMD=2.28;95%CI:1.24,3.32).

Conclusion: Selective trunk exercises, sitting reaching protocol and weight-shift training seem to provide beneficial effects for treating trunk impairment post-stroke. Furthermore, all protocols had superior effects on some phases post-stroke compared to control therapy. Future research should investigate the effect of trunk rehabilitation in the (hyper-)acute phase post-stroke.

1.Introduction

Stroke is a frequently observed neurological disorder that entails a major impact to the ones suffering from it on several aspects of everyday life. In 2010, the estimated worldwide incidence for stroke was 16.9 million, with a total of 102.2 million disability-adjusted life years (DALY's) lost.[1] In the past few decades, studies have been published establishing an evidence-base of rehabilitation post-stroke. Stroke rehabilitation can be subdivided in 5 different time phases; hyperacute (0-24 hours), acute (1-7 days), early subacute (7 days – 3 months), late subacute (3 – 6 months) and chronic phase (>6 months).[2] Motor rehabilitation post-stroke includes common elements throughout the different stages but also differences in the therapeutic approach.[3]

One key motor impairment post stroke is a deficit in trunk performance, which is a well-recognized and important predictor of overall function post-stroke.[4–6] Verheyden et al found trunk performance, measured by the Trunk Impairment Scale (TIS) total score and static sitting balance subscale, to be the most important predictor of functional outcome at 6 months post-stroke.[7] Trunk muscles connect different structures, more specifically head, spine, pelvis, rib cage and shoulder girdle. Due to this multidirectional muscular connection, the trunk is essential for a wide range of activities, such as head and upper limb movement, gait and breathing.[8] Reduced neural signal transmission between brain and trunk muscles after stroke can lead to a wide range of movement impairments.

Literature presents two key motor issues related to trunk muscle deficits, which are impaired sitting balance and reduced reaching ability from sitting.[9]
First, balance is defined as "the ability to statically or dynamically control one's body position in space over the base of support".[10] To execute a wide range of functional activities correctly, sitting balance is a primary requirement. More specific pro- and reactive trunk movements are important to maintain postural control. Perlmutter et al reported that stroke patients in the chronic phase show an increased sway area compared to controls while sitting, which may impair these functional activities.[11] The function of the muscles of the trunk, which are typically impaired in stroke, is essential for balance, transfers, gait and many other activities of daily living.[12,13]
Second, reaching activities are typically impaired in stroke patients. Messier et al did a dynamic analysis of trunk flexion after stroke. They found that trunk flexion occurred with a diminished

displacement of the center of pressure (COP) and with less weight-bearing on both feet, indicating body mass to be less moved anteriorly.[14] Findings from Dean et al support the reduced weight-bearing on both feet, and found trunk movements in post-stoke patients to be slower to avoid balance threats.[15]

Evidence among implementing trunk rehabilitation in post-stroke rehabilitation is rising, as well as the interest of researchers to publish about the specifications of administering trunk training in clinical practice. Cabanas-Valdés et al conducted a systematic review published in 2013 on effectiveness of trunk training exercises (TTE) on a variety of outcome measures.[9] TTE was defined as "exercise training for trunk muscles, performed in sitting or supine, specifically aimed at improving trunk performance and functional sitting balance under the supervision of a therapist"[9]. A further division of TTE was made into the sitting training protocol (STP) and the trunk exercises (TE) protocol. They defined the sitting training protocol (STP) as "a training exercise program designed to improve the ability to balance in sitting by reaching beyond arm's length using the unaffected hand whilst focusing on: 1) smooth coordinated motion of the trunk and arm to get the hand to the object; 2) appropriate loading of the affected foot; and 3) preventing the use of maladaptive strategies such as widening the base of support"[9]. Trunk exercises (TE) was defined as "selective movements of the upper and lower part of the trunk and raising the upper extremities in supine and/or sitting position"[9]. Their search strategy with literature included until November 2012 yielded 11 RCTs with in total 317 participants, from which five and six used the STP and the TE regimen, respectively. STP studies showed consistent improvement in maximum reach distance in three directions (forward, ipsilateral, contralateral), measured by the modified functional reach test[16]. TE studies found a significant improvement of sitting balance, assessed by the Trunk Impairment Scale and its subscales[17]. TTE significantly improved static standing balance, gait and mobility.[9]
Sorinola et al performed another systematic review and meta-analysis also published in 2013 on the effect of additional exercise on trunk outcome.[18] Additional exercise was defined as "specific trunk exercises in lying and sitting or other specific interventions such as sitting balance training, weight shifting in sitting and arm reaching in sitting"[18]. Their search strategy until July 2012 and inclusion criteria yielded 6 RCTs, with a total of 155 participants. They conducted a meta-analysis and reported beneficial, but no significant effects of additional exercise on trunk performance, functional independence and standing balance. However, they found a significant positive effect on mobility.[18]

Bank et al investigated the effect of any additional physiotherapy on sitting balance in stroke patients in a third systematic review.[19] They included 11 studies, all together accounting for 453 participants. Meta-analysis showed significant improvements in sitting balance as measured by the TIS following any additional trunk therapy-based or other type of intervention.[19]

Finally, Van Criekinge et al investigated whether trunk rehabilitation on unstable surface surpasses stable surface rehabilitation.[20] They included 7 studies with a total of 184 stroke patients. Four studies showed significant greater improvements in the unstable surface group compared to the stable surface group, as measured by TIS total, coordination and dynamic subscale and motor assessment scale (MAS)[21]. Furthermore, gait improved significantly more when training on unstable surface. Inconsistent results were found regarding standing balance.[20]

Because the findings of these four reviews were inconsistent with sometimes a different and limited focus, it is difficult to draw a clear conclusion. Furthermore, several recent studies on the effectiveness of trunk training post stroke have been published which are not incorporated in these 4 systematic reviews. Therefore, the aim of this study is to conduct an updated search and summarize the evidence on efficacy of trunk training on trunk performance post stroke. More specifically, the effect of several trunk rehabilitation modalities in the different phases post-stroke will be reviewed.

2.Methods

2.1 Inclusion criteria

Only studies with full text articles written in English, Dutch, German or French were included. Furthermore, selection of studies to be included in this review occurred according to the following inclusion criteria:

2.1.1 Eligible study type

Randomised controlled trials (RCT).

2.1.2 Participants

Included patients for this study were adult patients (≥18 years old) rehabilitating from hyperacute (0-24 hours), acute (1-7 days), early subacute (7 days – 3 months), late subacute (3 – 6 months) or chronic stroke (>6 months).[2] The participants could not have had any other disease that might affect trunk performance or sitting balance, and had to be able of understanding instructions.

2.1.3 Rehabilitation protocols

Types of interventions to be included provide exercise training specifically aimed at trunk function, performed in sitting or supine, with a clear focus on improving trunk performance and (functional) sitting balance with or under the supervision of a physiotherapist. We will further subdivide therapy provided in the following categories (to allow subgroup analysis):

(1) Core stability training: exercises specifically aimed at mainly isometrically strengthening core muscles in sitting or supine position. These exercises consist mostly of combined movements like bridging exercises, where not solely core muscles are involved. However, the main emphasis is on the trunk. In core stability training the trunk muscles are often activated simultaneously, without targeting specific independent single muscle groups.

(2) Selective trunk exercises: exercises in sitting or supine position that involve specific movements of lower and upper part of the trunk. Examples could be lateroflexion, rotation and flexion/extension. Typically, the aim of the exercises was enhancing trunk coordination and control, as well as strengthening specific trunk muscle groups.

(3) Electrostimulation: activation of trunk muscles by means of directly stimulating muscle (Neuro-Muscular Electrical Stimulation (NMES)) or nerve tissue (Transcutaneous Electrical Nerve Stimulation (TENS)).

(4) Weight-shift training: training protocol whereby the patient moves his/her weight from one buttock towards the other in a seated position with both feet supported by the ground.

(5) Sitting reaching protocol: as defined by Cabanas-Valdés et al: "a training exercise program designed to improve the ability to balance in sitting by reaching beyond arm's length using the unaffected hand whilst focusing on: 1) smooth coordinated motion of the trunk and arm to get the hand to the object; 2) appropriate loading of the affected foot; 3) preventing the use of maladaptive strategies such as widening the base of support".[9]

(6) Unstable surface: the use of objects to be inserted underneath (part of) the base of support of the patient, with the purpose to provide postural disturbances, which challenges the balance ability of the patient. These objects are most often filled with air or foam. They are mostly used to make trunk exercises more challenging, but also for practicing static sitting balance.

(7) Static inclined surface: exercises or static sitting balance is practised on a flat stable surface that is inclined some degrees from the horizontal reference in the frontal or sagittal plane.

All types of control conditions, i.e. no therapy or sham/placebo conditions with the same therapy dose but a passive or active treatment strategy were included.

2.1.4 Outcome measures

Outcome measures for this report had to be valid and reliable for the assessment of trunk performance, as this is the focus of this manuscript. Furthermore, all assessments needed to test in supine or sitting position.

2.2 Search strategy

Studies were selected by computer supported electronic searches in MEDLINE (Pubmed), EMBASE, CINAHL, Cochrane Central Register of Controlled Trials (CENTRAL) and PEDro. The PubMed search strategy was used as a template for searching other databases and is provided in Appendix 1. The search strategy covered studies published from November 2012 until October 2017, starting from the point where Cabanas-Valdés et al[9] ended their electronic search. All papers identified and included by Cabanas-Valdés[9], Sorinola[18], Bank[19] and van Criekinge[20] were also included in the present review, if adhered to our in- and exclusion criteria.

2.3 Review methods

Title and abstract from studies selected by the search strategy were read and verified for selection criteria by two different authors (AL and SD). Clearly irrelevant studies were excluded before reading full text of potential useful or doubtful studies. Verification of the final selection was conducted by a third author (GV).

Two assessors independently verified the methodological quality of the included studies by using the PEDro scale[22] with scores ranging from 0 to 10, where a higher score represents better methodological quality.

2.4 Statistical analysis

After extracting the required data from the included studies, Review Manager 5.3 software was used to present the findings of the included studies in this review graphically by means of forest plots. More specifically, for both experimental group(s) and control group the sample size and the between group mean change along with its standard deviation was entered to calculate effect sizes across different measurement tools used, but only for tools evaluating trunk performance/sitting balance. We applied a random effects model for our meta-analyses. Missing data was firstly requested by contacting the corresponding author. In case of absence of response, data was obtained by means of the forest plots created in the systematic review of Cabanas-Valdés et al.[9] Categorization of effect sizes occurred according to the Cochrane Handbook for Systematic Reviews[23], which proposes following categorization based on magnitude of effect sizes (Standardized Mean Difference (SMD)): small (<0.20), moderate (0.50 – 0.80) and large (>0.80).[23]

3. Results

Our search strategy yielded 2802 studies, which were primarily screened based on title and abstract (figure 1). A total of 2750 studies were excluded at title and abstract screening stage for not reporting about trunk rehabilitation in sitting or supine. The remaining 52 papers were further screened for in- and exclusion by reading the full text articles, whereby another 35 studies were excluded.

The main reasons for exclusion were: outcome measures lacking psychometric evaluation, outcome measures not focusing on the trunk, language other than English, Dutch, German or French, therapy not performed in sitting or supine position or no randomized controlled trial. A total of 17 studies were included based on our search strategy.

Searching the four reviews yielded an additional 35 studies, of which 22 were excluded for being a duplicate of another review or not reporting about trunk rehabilitation in sitting or supine. Based on further screening, another four studies were excluded. Overall, 9 additional studies were included in our review, which resulted in a total of 26 trials.

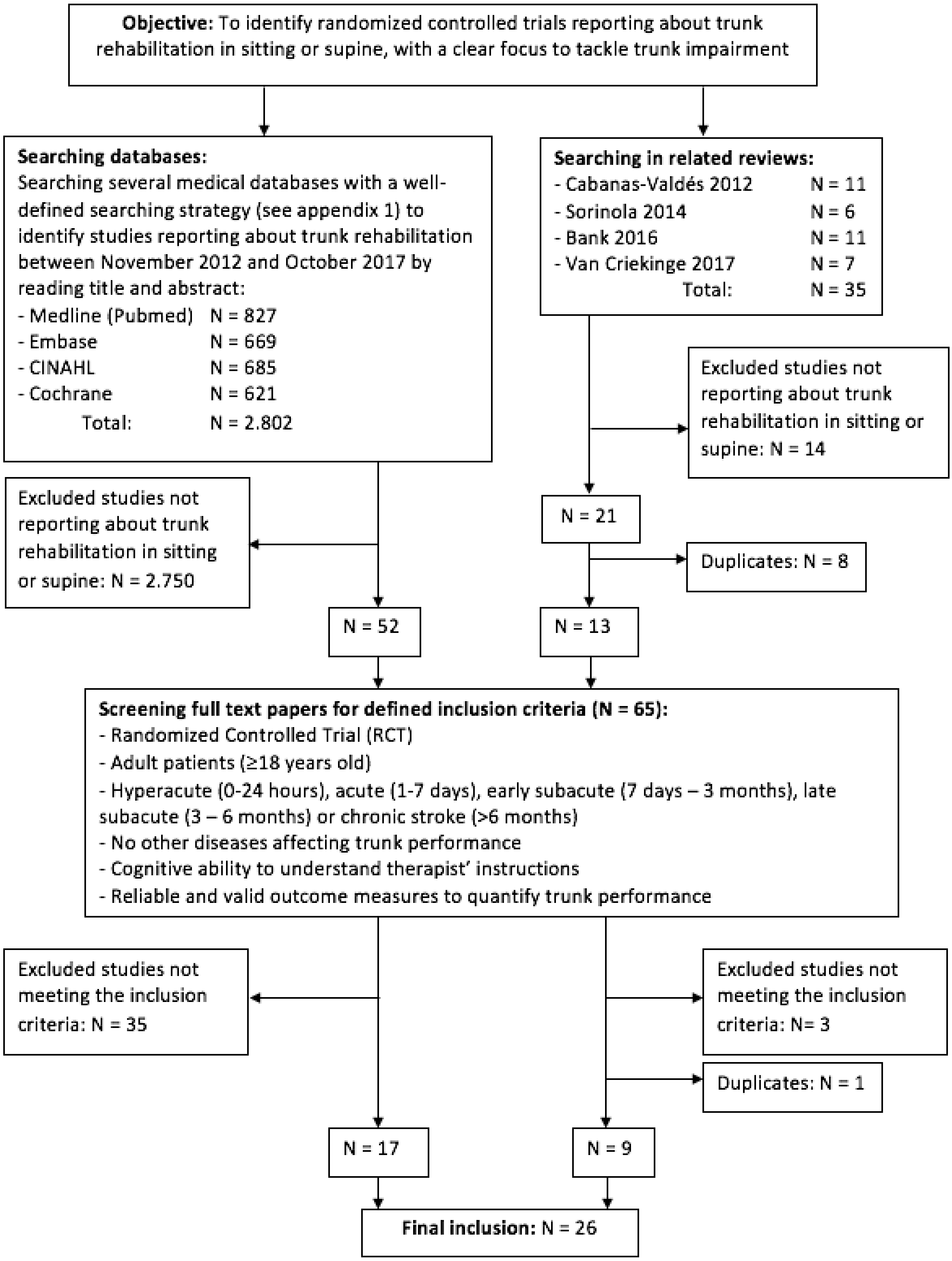

Figure 1 Flow chart of the review process.

	Participants						Intervention			Results				
Study	*N (Exp/cont)*	*Age (yrs)*	*Sex ratio (M/F)*	*MTPS (mean time post stroke)*	*Rehab phase*	*(I/H)*	*Experimental*		*Control*	*Outcome Meausures*	*Change Experimental (Mean ± SD)*	*Change Control (Mean ± SD)*		*Between group difference*
Bae 2013	16 (8/8)	E: 52.4 ± 7.6	E: 4/4	E: 18.1 ± 4.2 m	Chronic	11/5	CT: 12wk		CT: 12wk	TIS total ▿	3.7 ± 1.72*	1.8 ± 1.8*		
		C: 53.4 ± 5.8	C: 5/3	C: 17.9 ± 4.3 m			AT: 12wk, 5/wk, 30'		AT: 12wk, 5/wk, 30'	Static balance (SP (mm)) ▿	*	*		
										Static balance (SA (mm2)) ▿		*		
										Dynamic balance (SAP (mm/s)) ▿				
Büyükavci 2016	64 (32/32)	E: 62.6 ± 10.5	E: 17/16	E: 33.4 ± 11.4 d	Early	52/12	CT: 3wk, 5/wk, 120-180'		CT: 3wk, 5/wk, 120-180'	TIS total	*	*		No p= 0.772
		C: 63.6 ± 10.4	C: 15/17	C: 36.5 ± 19.9 d			AT: 3wk, 5/wk, ≥120'			TIS static	*	*		No p= 0.739
										TIS dynamic	*	*		No p= 0.661
										TIS coordination	*	*		No p= 0.838
Cabanas-Valdés 2016	79 (40/39)	E: 74.92 ± 10.70	E: 21/19	E: 25.12 ± 17.30 d	Acute + early	64/15	CT: 5wk, 5x/wk, 60'		CT: 5wk, 5x/wk, 60'	TIS 2.0 dynamic	4.10 ± 2.80*	1.82 ± 1.73		Yes p=0.001
		C: 75.69 ± 9.40	C: 18/21	C: 21.37 ± 16.00 d			AT: 5 wk, 5x/wk 15'			TIS 2.0 coordination	1.77 ± 1.20*	0.66 ± 0.86		Yes p=0.001
										TIS 2.0 total	5.88 ± 3.48*	2.48 ± 2.20		Yes p=0.001
										FIST	22.92 ± 14.31*	13.28 ± 11.80		Yes p=0.002
Cabanas-Valdés 2017	68 (36/32)	E: 75.08 ± 11.05	E: 17/19	E: 166.7 ± 44.9 d	Late + chronic	53/15	CT: 5wk, 5/wk, 60'		CT: 5wk, 5/wk, 60'	TIS 2.0 dynamic ▿	0.83 ± 1.18	0.31 ± 0.69		Yes p=0.026
		C: 75.81 ± 9.06	C: 17/15	C: 154.4 ± 18.2 d			AT: 5wk, 5/wk, 15'			TIS 2.0 coordination ▿	0.42 ± 0.77	0.15 ± 0.37		No
										TIS 2.0 total ▿	1.25 ± 1.25	0.47 ± 0.84		Yes p=0.003
										FIST ▿	3.36 ± 6.11	0.84 ± 2.09		Yes p= 0.009
Chan 2015	TENS + TRTT 12	58.2 ± 10.7	8/4	43.9 ± 28.4 m	Chronic	29/8	TENS + TRTT	pTENS + TRTT	Control		TENS + TRTT	pTENS + TRTT	Control	
	pTENS + TRTT 13	56.3 ± 7.4	10/3	41.8 ± 28.7 m			AT: 6wk, 5x/wk, 60'	AT: 6wk, 5x/wk, 60'	AT: 6wk, 5x/wk, 60'	TIS total	5.7 ± 1.7*	4.6 ± 1.3*	1.3 ± 1.5	Yes p<0.05
	Control 12	59.3 ± 10.4	9/3	47.3 ± 29.8 m						TIS static	0.4 ± 0.5	0.4 ± 0.5	0.1± 0.5	No
	Total: 37									TIS dynamic	2.9 ± 1.0*	2.8 ± 0.9*	0.3 ± 0.8	Yes p<0.05
										TIS coordination	2.4 ± 0.7*	1.5 ± 0.5*	0.5 ± 0.5*	Yes p<0.05
										Forward reach (cm)	7.4 ± 5.2	5.5 ± 10.7	-0.2 ± 8.7	No
										Reach non affected (cm)	5.5 ± 3.8*	3.1 ± 4.2	-2.2 ± 2.7	Yes p<0.05
										Reach affected (cm)	5.5 ± 4.7*	3.3 ± 4.1	-1.0 ± 2.8	Yes p<0.05
Choi 2014	30 (15/15)	E: 62.8 ± 9.00	E: 9/6	E: 13.00 ± 5.4 m	Chronic	/	CT: 4wk, 5/wk, 15'		CT: 4wk, 5/wk, 15'	mFRT (F) (cm)	6.1 ± 5.9*	2.4 ± 4.2*		No
		C: 65.1 ± 15.7	C: 7/8	C: 12.6 ± 5.7 m			AT: 4wk, 5/wk, 15'			mFRT (N) (cm)	5.7 ± 4.1*	1.9 ± 4.8		No
										mFRT (A) (cm)	3.4 ± 3.4*	1.3 ± 4.2		No
										COP VA (cm/s)	-0.6 ± 0.1	0.1 ± 0.1		No
										COP TPL (cm)	-1.7 ± 3.2	1.6 ± 4.1		Yes
Dean 1997	20 (10/10)	E: 68.2 ± 8.2	E: 7/3	E: 6.7 ± 5.8 y	Chronic	/	2wk, 5/wk, 30'		2wk, 5/wk, 30'	Reaching test:				
		C: 66.9 ± 8.2	C: 7/3	C: 5.9 ± 2.9 y						GRF across (% BW)	*			Yes p< 0.001
										GRF ipsilateral (% BW)				No
										GRF ant (% BW)	*	*		Yes p< 0.001
										Hand movement time ant (s)				No p= 0.048
										Hand movement time ipsi (s)	*			Yes p< 0.001
										Hand movement time acr (s)	*			Yes p< 0.001
										Max reach dist ant (mm)	1.21*	1.11*		Yes p< 0.001
										Max reach dist ipsi (mm)	1.11*	1.03		Yes p< 0.001
										Max reach dist acr (mm)	1.2*	1.08		Yes p< 0.001
Dean 2007	12 (6/6)	E: 60 ± 7	E: 5/1	E: 21 ± 8 d	Early	/	AT: 2wk, 5/wk, 30'		AT: 2wk, 5/wk, 30'	Sitting ability (max reach dist (m)) ▿	0.13 ± 0.05	-0.04 ± 0.03		Yes p<0.05
		C: 74 ± 12	C: 4/2	C: 37 ± 23 d						Sitting quality (reach time (s)) ▿	-0.04 ± 0.2	0 ± 0.3		Yes p<0.05
										Sitting quality (PVF (%BW)) ▿	13 ± 6	0 ± 5		Yes p<0.05
Dell'Uomo 2017	28 (14/14)	E: 54.21 ± 18.98	E: 8/6	/	Acute + early + late	/	CT: 6wk, 5/wk, 2x/d, 40'			TIS total ▿				Yes p<0.001
		C: 50.43 ± 17.49	C: 7/7	/			AT:			Sitting balance test ▿				Yes p=0.002
										TCT ▿				Yes p=0.002
Fujino 2015	43 (22/21)	E: 67.9 ± 7.8	E: 10/5	E: 10.6 ± 2.7 d	Early	20/10	CT: 1wk, each day, 60'		CT: 1wk, each day, 60'	TCT	12.60 ± 9.46*	4.13 ± 6.06		Yes p< 0.01
		C: 64.6 ± 7.5	C: 11/4	C: 10.2 ± 2.6 d			AT: 1wk, each day, 15'		AT: 1wk, each day, 15'					
Haruyama 2017	32 (16/16)	E: 67.56±10.11	E: 3/13	E: 66 (49.25-91.5) d	Early	14/18	CT: 4wk, 5x/wk, 40'		CT: 4wk, 5x/wk, 60'	TIS total	4.13 ± 2.31*	1.19 ± 1.42*		Yes p< 0.001
		C: 65.63±11.97	C: 4/12	C: 72 (48.25-93.5) d			AT: 4wk, 5x/wk, 20'			TIS static	0.63 ± 1.41*	0.06 ± 0.25*		No p= 0.064
										TIS dynamic	2.06 ± 1.65*	0.56 ± 0.73*		Yes p< 0.001
										TIS coordination	1.44 ± 1.50*	0.56 ± 1.26*		Yes p< 0.001
										Pelvic AROM (°)	9.94 ± 5.94*	1.19 ± 6.35*		Yes p< 0.001
Ibrahimi 2010	30 (15/15)	/	/	/	Acute + early	/	CT: 2wk		CT: 2wk	MAS sitting	*	*		Yes p<0.000
							AT: 2wk, 5/wk, 20-30'		AT: 2wk, 5/wk, 20-30'					
Jung 2014	17 (9/8)	E: 51.3 ± 10.3	E: 7/2	E: 15.3 ± 9.5 m	chronic	12/5	CT: 4wk, 5/wk, 30'		CT: 4wk, 5/wk, 60'	TIS total	*			Yes p=0.004
		C: 57.9 ± 8.5	C: 6/2	C: 14.4 ± 11.2 m			AT: 4wk, 5/wk, 30'			TIS static				No p=0.673
										TIS dynamic				Yes p=0.027
										TIS coordination	*			No p=0.093
										TRE (°)	*			Yes p=0.027

*Table 1: Study characteristics (▿ within group difference not reported, * significant difference)*

Study	Participants						Intervention			Results				
Study	*N (Exp/cont)*	*Age (yrs)*	*Sex ratio (M/F)*	*MTPS (mean time post stroke)*	*Rehab phase*	*(I/H)*	*Experimental*		*Control*	*Outcome Meausures*	*Change Experimental (Mean ± SD)*	*Change Control (Mean ± SD)*		*Between group difference*
Jung, Cho 2016	24 (12/12)	E: 58.9 ± 11.0	E: 8/4	E: 8.0 ± 3.2 m	Late + chronic	15/9	4wk, 5/wk, 30'		4wk, 5/wk, 30'	TIS total ▿	4.83 ± 2.17	2.42 ± 2.35		Yes
		C: 60.7 ± 7.8	C: 6/6	C: 8.4 ± 2.4 m						TIS static ▿	0.58 ± 0.79	0.67 ± 1.07		No
										TIS dynamic ▿	2.42 ± 1.42	0.92 ± 1.56		Yes
										TIS coordination ▿	1.83 ± 1.03	0.83 ± 1.19		Yes
Jung, Jung 2016	WSE + TENS 20	55.3 ± 8.3	12/8	5.6 ± 2.4 m	Late + chronic	36/24	WSE + TENS:	WSE + pTENS	Control		WSE + TENS	WSE + pTENS	Control	
	WSE + pTENS 20	55.4 ± 10.4	13/7	5.0 ± 2.1 m			CT: 6 wk, 5x/wk, 60'	CT: 6 wk, 5x/wk, 60'	CT: 6 wk, 5x/wk, 60'	TIS total ▿	5.42 ± 2.63	3.85 ± 3.21	1.60 ± 1.19	
	Control 21	56.1 ± 10.8	11/9	5.9 ± 2.2 m			AT: 6 wk, 5x/wk, 30'	AT: 6 wk, 5x/wk, 30'	AT: 6wk, 5x/wk, 30'	TIS static ▿				
	Total: 61									TIS dynamic ▿				
										TIS coordination ▿	2.10 ± 1.37	1.30 ± 0.66	0.55 ± 0.69	
										Max reaching distance (cm) ▿	4.73 ± 1.86	3.42 ± 1.89	2.13 ± 1.06	
										Muscle activity (%MVIC) ▿	11.09 ± 4.61	6.38 ± 2.94	2.66 ± 1.76	
Kartikbabu 2011	30 (15/15)	E: 59.8 ± 10.5	E: 8/7	E: 11.8 ± 8.1 d	Acute + early	17/13	CT: 3wk		CT: 3wk	TIS total	7,93 ± 1.28*	4.87 ± 1.25*		Yes p< 0.0001
		C: 55 ± 6.5	C: 9/6	C: 12.1 ± 7.5 d			AT: 3wk, 4/wk, 60'		AT: 3wk, 4/wk, 60'	TIS static	1.27 ± 0.59*	1.2 ± 0.68*		No
										TIS dynamic	4.07 ± 1.34*	2.6 ± 0.98*		Yes p< 0.002
										TIS coordination	2.53 ± 0.52*	1.2 ± 0.41*		Yes p< 0.0001
Kilinc 2016	22 (12/10)	E: 55.91 ± 7.92	E: 4/8	E: 58.66 ± 55.68 m	Acute + early + late	11/11	AT: 12wk, 3x/wk, 60'		CT: 12wk, 3x/wk, 60'	TIS total	2.10 ± 1.28*	0.66 ± 0.86*		No p=0.62
		C: 54 ± 13.64	C: 5/5	C: 67.20 ± 43.17 m						TIS static	0.6 ± 0.96	0.00 ± 0.00		No p= 0.37
										TIS dynamic	1.10 ± 0.87*	0.66 ± 0.86*		No p= 0.71
										TIS coordination	0.40 ± 0.84	0.00 ± 0.00		No p= 0.91
Ko (Ho Chun) 2016	CMS: 12	59.5 (53.5-71.5)	8/2	12 (8-14.3) d	Acute + early	26/4	Combination:	CMS:	TNMES	TIS total				
	TNMES: 11	65.5 (49.8-69)	4/6	8.5 (8-13.3) d			CT: 3wk	CT: 3wk	CT: 3wk	TIS static				
	Comb: 11	58.5 (54.5-72.5)	7/3	11 (8.5-13) d			AT: 3wk, 3/wk, 20'	AT: 3wk, 3/wk, 20'	AT: 3wk, 3/wk, 20'	TIS dynamic				
	Total: 34									TIS coordination				
Kumar 2011	20 (10/10)	E: 59.5 ± 12.09	E: 7/3	E: 15.0 ± 6.16 d	Acute + early	/	CT: 3wk		CT: 3wk	TIS total ▿	6.96 ± 1.28	3.13 ± 1.24		Yes p<0.000
		C: 57.8 ± 13.49	C: 5/5	C: 15.8 ± 10.69 d			AT: 3wk, 30h (total)			TIS static ▿	1.27 ± 0.59	1.23 ± 0.67		No p=0.612
										TIS dynamic ▿	4.07 ± 1.22	2.80 ± 0.98		Yes p<0.002
										TIS coordination ▿	2.23 ± 0.31	1.17 ± 0.51		Yes p<0.001
Lee 2012	28 (14/14)	E: 59.0 ± 11.0	E: 8/6	E: 34.4 ± 25.4 m	Chronic	/	CT: 6wk, 5/wk, 60'		CT: 6wk, 5/wk, 60'	TIS total	3.7 ± 2.3*	0.9 ± 1.4*		Yes p<0.05
		C: 62.3 ± 14.2	C: 10/4	C: 33.6 ± 15.9 m			AT: 6wk, 3/wk, 30'			mFRT (F) (cm)	16.4 ± 9.7*	4.1 ± 5.6*		Yes p<0.05
										mFRT (N) (cm)	8.71 ± 5.2*	1.8 ± 2.8*		Yes p<0.05
										mFRT (A) (cm)	5.3 ± 4.4*	1.7 ± 2.1*		Yes p<0.05
Lee 2016	10 (5/5)	E: 65.2 ± 5.0	E: 3/2	E: 3.1 ± 1.6 m	Early + late	8/2	CT: 4wk, 5/wk, 135'		CT: 4wk, 5/wk, 135'	TIS total	2.8 ± 1.3*	1.0 ± 0.7		Yes p= 0.009
		C: 66.2 ± 3.4	C: 2/3	C: 3.3 ± 1.1 m			AT: 4wk, 3/wk, 30'							
Saeys 2012	33 (18/15)	E: 61.94 ± 13.83	E: 9/9	E: 38.72 ± 15.09 d	Early	26/7	CT: 8wk		CT: 8wk	TIS total	8.72 ± 1.97*	2.87 ± 2.39*		Yes p< 0.001
		C: 61.07 ± 9.01	C: 8/7	C: 32.07 ± 25.98 d			AT: 8wk, 4/wk, 30'		AT: 8wk, 4/wk, 30'	TIS static	1.56 ± 1.72*	1.47 ± 1.25*		Yes p< 0.001
										TIS dynamic	4.39 ± 1.195*	1.33 ± 1.4*		Yes p< 0.001
										TIS coordination	2.78 ± 1.53*	0.06 ± 0.7*		Yes p< 0.001
Sharma 2017	23 (13/10)	E: 57.23 ± 7.39	/	E: 12.15 ± 3.89 m	Chronic	/	4wk, 5/wk, 60'		4wk, 5/wk, 60'	TIS total	*	*		Yes p≤ 0.05
		C: 57 ± 8.26	/	C: 13.30 ± 4.27 m										
Shin 2016	24 (12/12)	E: 57.75±14.03	/	E: 17.58±10.04 m	Chronic	5/19	CT: 4wk, 5x/wk, 80'		CT: 4wk, 5x/wk, 80'	TIS total	3.08±2.71*	0.08±1.24		Yes p<0.05
		C: 59.25±9.75	/	C: 15.17±7.13 m			AT: 4wk, 3x/wk, 20'			Eyes closed (ML) (mm/s)	-1.33±1.07*	-0.19±1.29		Yes p<0.05
										Eyes closed (AP) (mm/s)	-1.37±1.15*	-0.03±1.89		Yes p<0.05
										Eyes closed (VM) (mm2/s)	-2.40±2.01*	-0.08±2.57		Yes p<0.05
										Eyes open (ML) (mm/s)	-0.86±0.83*	-0.12±1.28		Yes p<0.05
										Eyes open (AP) (mm/s)	-0.85±0.55*	-0.08±1.27		Yes p<0.05
										Eyes open (VM) (mm2/s)	-1.30±0.98*	-0.31±0.83		Yes p<0.05
										mFRT (F) (cm)	7.38±5.50*	1.00±0.63*		Yes p<0.05
										mFRT (N) (cm)	8.35±4.50*	3.45±5.46*		Yes p<0.05
										mFRT (A) (cm)	6.33±3.79*	1.70±1.13*		Yes p<0.05
Verheyden 2009	33 (17/16)	E: 55 ± 11	E: 11/6	E: 53 ± 24 d	Early	28/5				TIS total	4.82 ± 2.9*	3.31 ± 2.75*		Yes p< 0.001
		C: 62 ± 14	C: 9/7	C: 49 ± 28 d						TIS static	0.53 ± 0.87*	0.69 ± 1.25*		Yes p=0.003
										TIS dynamic	3.47 ± 1.81*	1.25 ± 2.02*		Yes p< 0.001
										TIS coordination	0.82 ± 1.13*	1.38 ± 0.81*		Yes p< 0.001
Yoo 2010	59 (28/31)	E: 59.61 ± 18.16	E: 13/15	E: 42.86 ± 35.08 d	Acute + early	29/30	CT: 4wk, 3/wk		CT: 4wk, 3/wk	TIS total	4.78 ± 3.99*	2.45 ± 2.11*		Yes p= 0.015
		C: 61.77 ± 12.58	C: 17/14	C: 48.03 ± 29.45 d			AT: 4wk, 3/wk, 30'			TCT	8.28 ± 13.93*	7.77 ± 18.62*		No p= 0.428

*Table 1: Study characteristics (continued) (▿ Within group difference not reported, * Significant difference)*

The total 26 eligible studies are listed in table 1. Appendix 2 lists the explanation of used abbreviations in table 1. Appendix 3 provides an overview of the administered experimental, control and additional therapies of the included studies. Authors of this list were contacted if there were any data lacking to calculate the effect sizes of their reported trunk or sitting balance outcome measures. Eventually, seven studies[24–30] could not be included in our meta-analysis due to missing data. Reasons were absence of author response (n=5), only reporting follow-up data (n=1) and loss of data because of a computer problem of one investigator (n=1).

The total population studied by the 26 trials is 877 participants, of which a known 433 subjects were male and 350 subjects were female (data about gender is lacking in Ibrahimi et al 2010[26], Sharma et al 2017[24] and Shin et al 2016[31]). A total known 456 participants suffered an ischemic stroke and 212 participants suffered a hemorrhagic stroke (data about type of stroke is lacking in Choi et al. 2014[32], Dean et al. 1997[15], Dean et al. 2007[33], Dell'Uomo et al. 2017[27], Ibrahimi et al. 2010[26], Kumar et al. 2011[34], Lee et al. 2012[35] and Sharma et al. 2017[24]).

To reflect the methodological quality of the included studies, individual PEDro scores of all 26 studies are listed in table 2. Maximal score on the PEDro scale is normally 10. However, due to inability to blind the therapists and the participants, the highest PEDro score in this review is 8. The mean PEDro score was 6.08 (range 4-8), representing a moderate to high quality in terms of methodology of studies included in this review. [22]

Study Item:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	***Total***
Bae 2013	Yes	No	Yes	No	No	No	No	No	Yes	Yes	*4/10*
Büyükavci 2016	Yes	No	No	No	No	Yes	Yes	No	Yes	Yes	*5/10*
Cabanas-Valdés 2016	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	*7/10*
Cabanas-Valdés 2017	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	*6/10*
Chan 2015	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	*8/10*
Choi 2014	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	*6/10*
Dean 1997	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	*7/10*
Dean 2007	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	*7/10*
Dell'Uomo 2017	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes	*6/10*
Fujino 2015	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	*6/10*
Haruyama 2017	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes	*6/10*
Ibrahimi 2010	Yes	No	Yes	No	No	No	No	No	Yes	Yes	*4/10*
Jung 2014	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	*7/10*
Jung, Cho 2016	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	*5/10*
Jung, Jung 2016	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	*7/10*
Karthikbabu 2011	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	*7/10*
Kilinc 2016	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes	*6/10*
Ko (Ho Chun) 2016	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes	*6/10*
Kumar 2011	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes	*6/10*
Lee 2012	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	*5/10*
Lee 2016	Yes	No	Yes	No	No	Yes	No	No	Yes	Yes	*5/10*
Saeys 2012	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	*7/10*
Sharma 2017	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	*7/10*
Shin 2016	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes	*6/10*
Verheyden 2009	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes	*6/10*
Yoo 2010	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	*5/10*

Table 1 PEDro scores of all included studies. Studies not included in the meta-analysis are shaded grey.

1: Random Allocation, 2: Concealed allocation, 3: Baseline similarity, 4: Participant Blinding, 5: Therapist Blinding, 6: Assessor Blinding, 7: <15% Drop-outs, 8: Intention to Treat analysis, 9: Between Group Comparison, 10: Point Measures and Variability Data

All included studies reported one or more validated trunk outcome. Trunk performance was assessed by the trunk impairment scale[17] (n=19), trunk impairment scale 2.0 (Spanish version)[36] (n=2), trunk control test[37] (n=1), MAS sitting subscale[21] (n=1), modified functional reach test[16] (n=1) or derivatives of the mFRT[15,33] (n=2). The total number of included participants varied per study from minimum 10[38] to maximum 79[39], with an average number of participants per study of 34. Therapy doses range from 2 weeks to 12 weeks, 3 times a week to each day and 15 minutes to 120 minutes per session.

Selective trunk exercises (Figure 2)

The meta-analysis for selective trunk exercises shows a significant large effect of selective trunk exercises on trunk performance based on 3 studies[34,40,41] in the early subacute phase (SMD = 1.96; 95% CI 0.32, 3.60), as well as based on 1 study[42] in the chronic phase (SMD = 2.28; 95% CI 1.24, 3.32). Overall, based on 4 studies[34,40–42] there is a significant large effect (SMD = 2.03; 95% CI 0.80, 3.25) of selective trunk exercises on trunk performance post stroke.

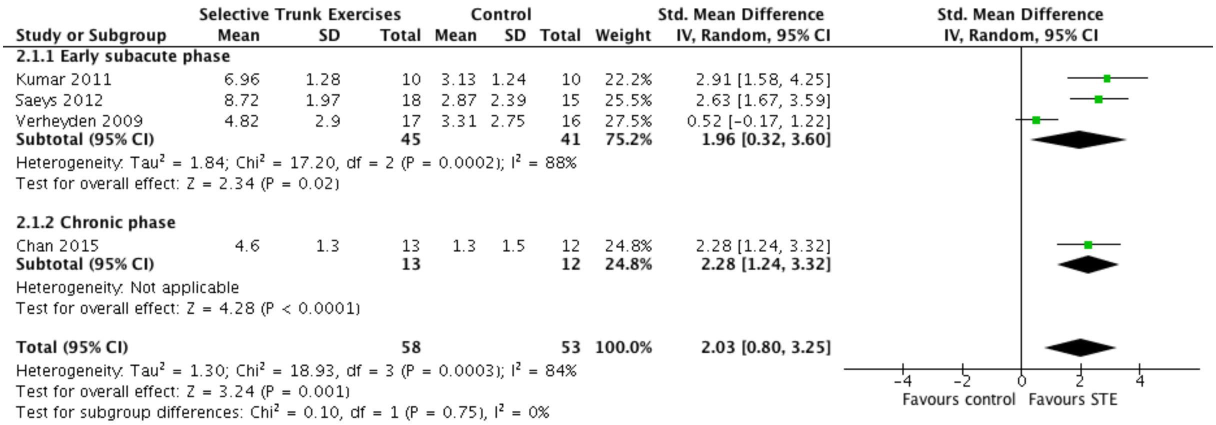

Figure 2 Selective Trunk Exercises (STE)

Core stability training (Figure 3)

The forest plot visualizing core stability training shows a significant large effect of core stability training on trunk performance based on 3 studies[39,43,44] in the early subacute phase (SMD = 1.06; 95% CI 0.67, 1.46), as well as based on 1 study[45] in the chronic phase (SMD = 1.25; 95%CI 0.31, 2.18). Overall, based on 4 studies[39,43–45] there is a significant large effect (SMD = 1.07; 95% CI 0.77, 1.38) of core stability training on trunk performance post stroke.

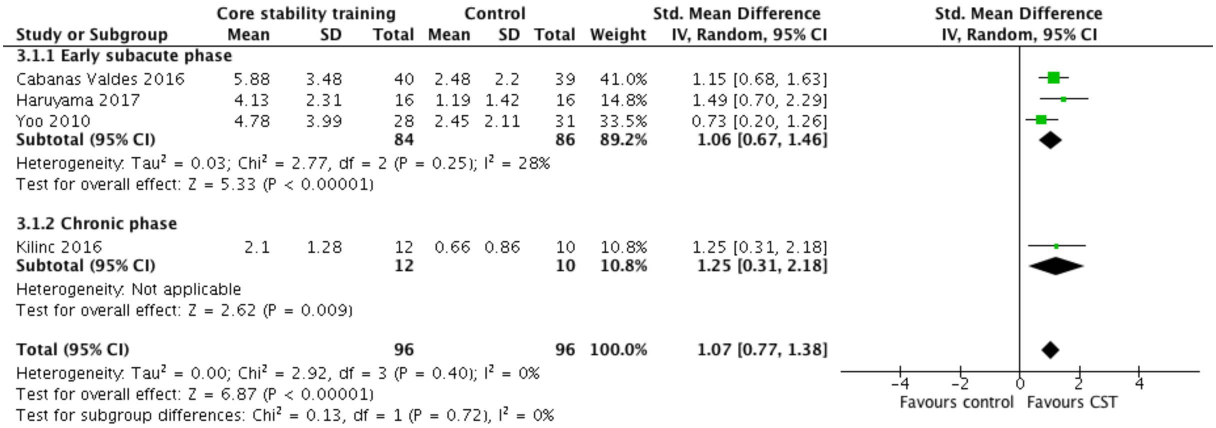

Figure 3 Core stability training (CST)

Electrostimulation (Figure 4)

Electrostimulation shows a significant moderate effect of electrostimulation on trunk performance based on 1 study[46] in the late subacute phase (SMD = 0.75; 95% CI 0.11, 1.39). Additionally, it shows a non-significant effect of electrostimulation on trunk performance based on 1 study[42] in the chronic phase (SMD=0.71;95% CI -0.11, 1.52).

Overall based on 2 studies[42,46] there is a significant moderate effect (SMD=0.73;95%CI 0.23, 1.24) of electrostimulation on trunk performance.

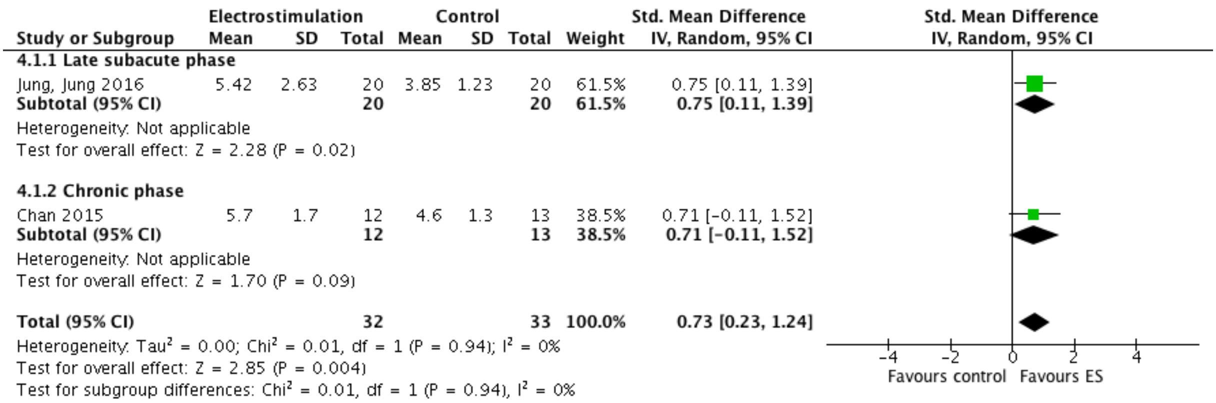

Figure 4 Electrostimulation (ES)

Weight-shift training (Figure 5)

The meta-analysis for weight-shift training shows a significant large effect of weight-shift training on trunk performance based on 2 studies[38,46] in the late subacute phase (SMD = 1.77; 95% CI 1.11, 2.44), as well as based on 1 study[31] in the chronic phase (SMD = 1.37; 95% CI 0.47, 2.28). Overall, based on 3 studies[31,38,46] there is a significant large effect (SMD = 1.63; 95% CI 1.10, 2.17) of weight-shift training on trunk performance post stroke.

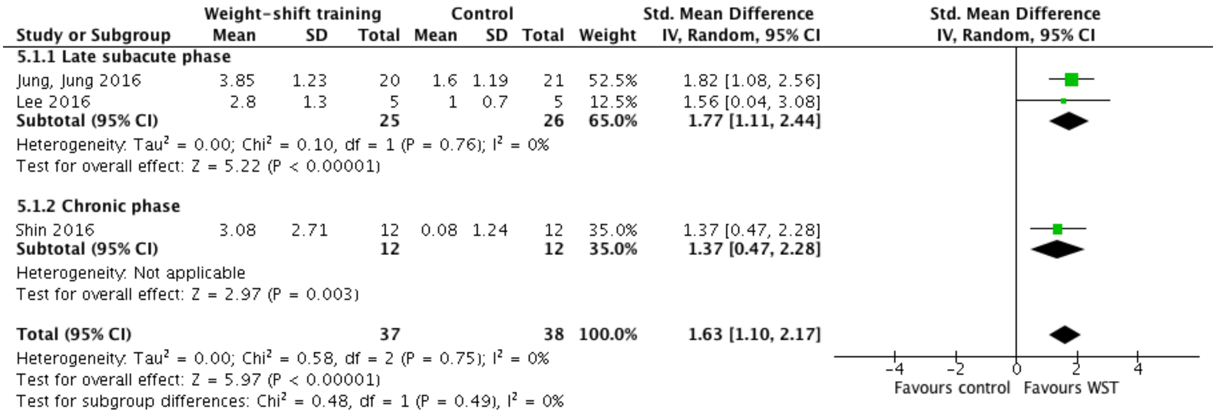

Figure 5Weight-shift training (WST)

Sitting reaching protocol (Figure 6)

Analysis of the sitting reaching protocol shows a significant large effect of reaching in sitting on trunk performance based on 1 study[33] in the early subacute phase (SMD=3.81;95%CI 1.63,5.98), as well as based on 1 study[15] in the chronic phase (SMD=1.06;95%CI 0.08, 2.04). Overall, based on 2 studies[15,33] the effect of reaching in sitting position on trunk performance is non-significant (SMD=2.25; 95%CI -0.41, 4.92).

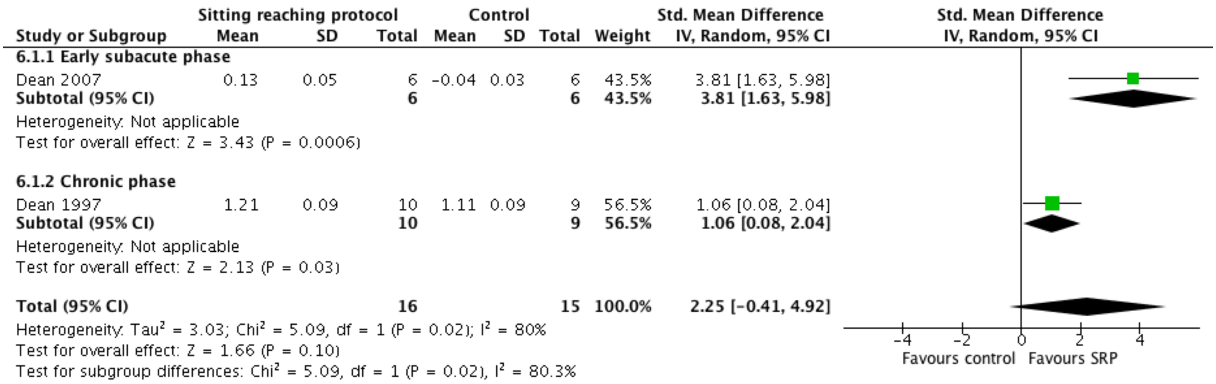

Figure 6 Sitting reaching protocol (SRP)

Unstable surface (Figure 7)

The forest plot visualizing unstable surface rehabilitation shows a significant large effect of incorporating an unstable surface in therapy on trunk performance based on 1 study[47] in the early subacute phase (SMD = 2.35; 95% CI 1.39, 3.31), as well as based on 4 studies[32,35,48,49] in the chronic phase (SMD=1.02; 95% CI 0.59, 1.45). Overall, based on 5 studies[32,35,47–49] there is a large effect (SMD=1.28; 95% CI 0.73, 1.83) of unstable surface training on trunk performance post stroke.

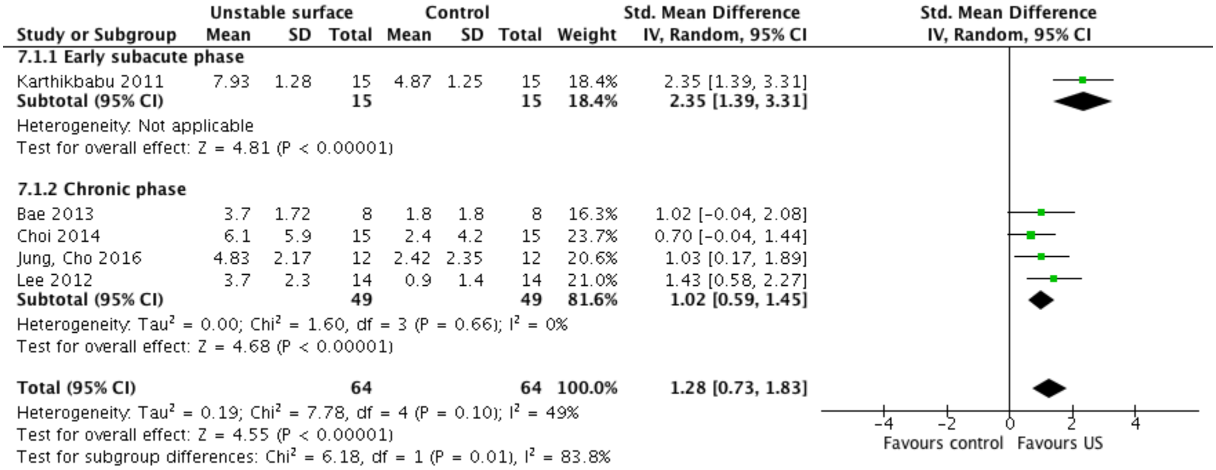

Figure 7 Unstable surface (US)

Static inclined surface (Figure 8)

The meta-analysis for static inclined surface rehabilitation shows a significant large effect of incorporating a static inclined surface in therapy on trunk performance based on 1 study[50] in the early subacute phase (SMD=1.04;95%CI 0.40, 1.68).

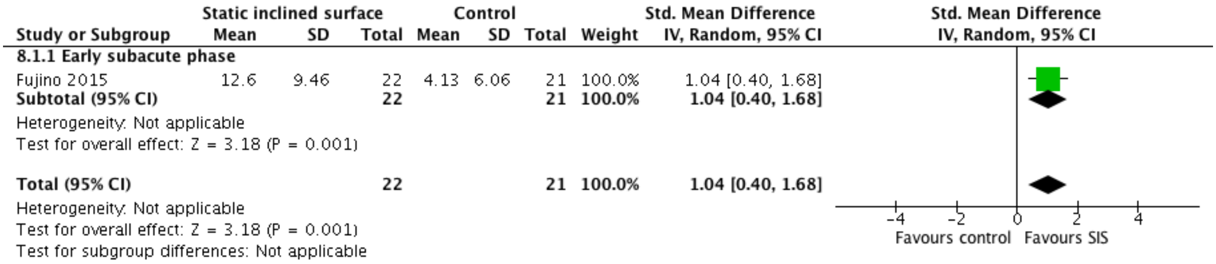

Figure 8 Static inclined surface (SIS)

4. Discussion

4.1 Summary of meta-analyses

The purpose of this review was to investigate the effect of several protocols to improve trunk impairment in the different phases post-stroke. 19 trials were included in the meta-analysis, more specifically in the forest plots of the trunk rehabilitation strategy it investigates. Categorization of individual study interventions into protocols yielded 7 strategies to tackle trunk impairment, of which 6 show significant improvements in trunk performance compared to the control condition post-stroke, namely selective trunk exercises, core stability training, electrostimulation by means of TENS, weight-shift training, and implementing an unstable or static inclined surface in trunk therapy. The selective trunk exercises yielded the largest significant effects on trunk performance overall. Reaching was not shown to significantly improve trunk performance post stroke overall, however it did improve trunk performance in the early acute and chronic phase post-stroke. Considering the different phases post-stroke, 5 protocols were found to be superior to control condition in improving trunk performance in the early subacute phase post-stroke, of which the reaching protocol showed the largest effect. Only 2 protocols were investigated in the late subacute phase. Both showed significant superiority of trunk rehabilitation compared to the control condition whereby weight-shift training has the largest effect size. In the chronic phase, 6 protocols displayed a trend towards favorable effects over control condition, of which 5 did report a significant difference. Electrostimulation however did not. Selective trunk exercises appeared to be the favorable protocol in this phase based on the largest effect size. The 4 studies[33,38,42,46] displaying the largest effect in the 3 phases post-stroke seem to agree on a therapy amount of 5 times a week, 60 minutes per day, except for Dean et al[33] who reported sessions of 30 minutes per day. Indistinctness remains regarding the number of weeks to offer the intervention. 2 studies agreed[42,46] on 6 weeks, 1 study[38] reported 4 weeks and 1 study[33] reported only 2 weeks of intervention to obtain the reported effects.

4.2 Discussing limitations of 4 prior systematic reviews

Similar reviews discussing the evidence-base for treatment of trunk impairment have been published in the last decade. Cabanas-Valdés et al.[9] was the first to categorize trunk rehabilitation in different protocols, namely trunk exercises and sitting reaching protocol. A meta-analysis however was not possible, so no clear conclusion could be drawn to support the use of trunk training exercises over other therapy modalities to improve trunk performance. Moreover, they did not compare the sitting reaching protocol and the trunk exercises protocol, thus superiority of one protocol over the other remains inconclusive. Finally, trials reporting about trunk rehabilitation by means of electromechanical devices were excluded. Regarding therapy dose, Sorinola et al.[18] firstly assessed the role of additional trunk exercises in therapy to enhance trunk function in post-stroke patients. They found a trend towards a favorable effect of additional exercise on trunk performance. However, the small number of trials included in the analysis prevents clear interpretation. Bank et al.[19] conducted a comparable investigation on the effect of any additional physical therapy on sitting balance. Despite the implementation of a substantial amount of trials, the quality of some included trials was relatively low, and large treatment heterogeneity was reported to be present. The most recent review published about trunk rehabilitation post-stroke was conducted by Van Criekinge et al.[20] who assessed the possible superiority of implementing an unstable support surface over a stable support surface in therapy. Their findings show a tendency towards implementing unstable surfaces in therapy to treat trunk impairment, which is supported by our meta-analysis of unstable surface rehabilitation (Figure 7). Their data however displayed a high between subgroup heterogeneity. No subdivision of post-stroke phase was made in the analysis, making it difficult to pinpoint which patient population benefits most from unstable surface rehabilitation. Furthermore, the low amount of included trials force the results to be interpreted with caution.

Therapists are confronted with limited therapy time to achieve the largest possible improvement in trunk performance in post-stroke patients. Recent publications magnify the therapist's tool box in doing so. Combined with current knowledge on the natural course of regeneration after stroke, there is a need for a clear understanding which tools should be used in rehabilitating trunk in the different regeneration phases post-stroke. Based on the limitations of former reviews, the current review aimed to implement a subdivision in therapy and rehabilitation phase in the meta-analysis, thereby trying to fill the gaps in common understanding of trunk rehabilitation post-stroke. The visualization of a larger amount of included trials aids in doing so.

4.3 Considerations regarding interpretation of results

Some considerations are important when interpreting the results of this meta-analysis. In the early subacute phase, all 5 protocols had a significant large effect on trunk performance, with the reaching protocol showing the largest effect. This effect is based on 1 trial[33] incorporating a small sample size of 12 participants, and thus caution is warranted as this study is underpowered. Additionally, 3 studies[15,32,33] used the mFRT or a derived variant as outcome measure, which does not directly measure trunk performance due to contribution of the unaffected upper limb in reaching movements. Despite the smaller effect sizes, selective trunk exercises and core stability training show more consistent and substantiated positive effects on trunk performance based on 3 studies[34,40,41] and larger sample sizes.

In the late subacute phase, the largest effect on trunk performance was reported to result from weight shift training. This needs to be interpreted with caution due to a passive control condition in Jung et al[46] and inequality in received therapy time to the disadvantage of the control condition in Lee et al[35].

In the chronic phase participants seemed to benefit most from the selective trunk exercises, although this finding solely relies on 1 study[42] examining 25 participants. Additionally, the large effect size might be explained by the control condition not receiving any active therapy. The 3 sub analyses for phases post-stroke had a high-quality study methodology, reflected by a mean PEDro score ≥6. Electrostimulation was shown to significantly improve trunk performance. However, only trials reporting about TENS were included in the meta-analysis. Ko et al did report about NMES, but could not be included in the meta-analysis due to missing data[25]. Thus, the effect of NMES on trunk performance remains unclear at present.

4.4 Contemplation of methods

The expanded search strategy used in this review yielded quite a considerable amount of new trials published after November 2012 who focused on trunk rehabilitation in sitting or supine and used validated outcome measures. Taking into account that only 4 medical databases were searched, the final selection was substantial. Especially frequently reported was the TIS as outcome measure. All trials matched a total of 7 protocols, which enlarges the former subdivision of only 2 protocols to tackle trunk impairment.

4.5 Other trunk rehabilitation modalities

Trials reporting about the beneficial effect of implementing advanced and game-based technology in therapy on different outcome measures like gait, balance and mobility are increasing rapidly.[51–54] Interventions integrating this technology in trunk rehabilitation also seems to gain popularity. Currently, a protocol has been proposed by Sheehy et al who will investigate the effect of additional virtual reality training on sitting balance and function post-stroke.[55] This review includes assessment by means of smartphone use as well as an intervention using virtual reality and game-based rehabilitation with Nintendo Wii©[31,38]. Due to categorization, the latter study was categorized as being weight-shift training, yet intervention effects might come partly from the advanced technology part. Few studies however investigated the direct effect of advanced technology on trunk performance, thus this effect remains poorly understood.

4.6 Future research recommendations

To our knowledge, this is the first meta-analysis to incorporate the division of different rehabilitation stages post-stroke in analyzing trunk rehabilitation. Already in early subacute phase post-stroke large effects of trunk rehabilitation are reported, supporting the hypothesis to start early with trunk training. Evidence however is lacking for the hyperacute and acute phase of stroke rehabilitation. This might be since (hyper)acute rehabilitation is conducted in the acute hospital setting rather than in the rehabilitation setting. Recommendations for future research rose from analyzing the data, which generally showed a need for larger study sample sizes and active control conditions to detect true effects, as well as establishing optimal therapy dose. Most trials assessed selective trunk exercises, core stability training and unstable surface rehabilitation, providing limited evidence for the remaining therapies. Administered therapy dose differed substantially between the studies, establishing the need for consensus about the amount of therapy. Finally, future research should investigate the follow-up effects of therapy, since this only was reported in 3 studies.[29,33,42]

4.7 Study limitations

Results of this review need to be considered with the awareness of some limitations.
7 studies did not report standard deviations along with the mean between group changes in their full text articles and did not respond to a request for additional data, thus could not be incorporated in the meta-analysis. Including this evidence would be of additional benefit. Categorization of study protocols is sensitive to subjectivity, yet this categorization was assessed by 4 independent assessors, reducing interpretation bias to a minimum. Heterogeneity was present in some parts of the meta-analysis and might be due to clinical heterogeneity (therapy dose and duration) and differences in methodological quality (PEDro score ranging from 4-8). 7 studies reported only fair quality of study methodology based on a PEDro score of 4 or 5, which still corresponds with acceptable methodological quality. It is unfortunately very hard to blind therapist and patient in rehabilitation research. It is to be noted that poor methodological quality studies were not included in the review.

5. Conclusion

This review and meta-analysis suggests a positive effect of trunk rehabilitation post-stroke, with selective trunk exercises, sitting reaching protocol and weight-shift training showing the largest effects. All protocols had a significant superior effect to control conditions in some phases post-stroke and selective trunk exercises currently tends to be the most effective strategy to tackle trunk impairment post-stroke. The number of publications of new trials reporting about trunk rehabilitation post-stroke is increasing, reflecting the need for clear guidelines about this topic in light of evidence-based clinical practice. This review contributes to understanding the core principles of effective trunk rehabilitation.

6. Acknowledgment

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7. Competing Interests

The authors declare to have no competing interests.

Clinical messages

The most effective strategies to improve trunk performance:

- In the early subacute phase post-stroke, the sitting reaching protocol is recommended. This consists of trunk training by means of reaching movements along with trunk displacement.
- In the late subacute phase the suggested strategy is weight-shift training by transporting weight between the buttocks.
- In the chronic phase, selective trunk exercises, being specific movements of lower and upper part of the trunk, are recommended.

The proposed amount of therapy is 6 weeks, 5 times a week, 60 minutes per session

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Appendix 1

Search Strategy (MEDLINE (Pubmed))

1. Stroke[Mesh] OR stroke*[tiab]
2. CVA*[tiab]
3. cerebrovascular accident*[tiab]
4. cerebrovascular incident [tiab]
5. #1 OR #2 OR #3 OR #4
6. Exercise Therapy[Mesh] OR Exercise Therap*[tiab]
7. postural balance[Mesh] OR postural balance[tiab]
8. postural equilibrium [tiab]
9. trunk training*[tiab]
10. trunk exercise*[tiab]
11. core stabilit*[tiab]
12. truncal exercise*[tiab]
13. sitting balance*[tiab]
14. reaching[tiab]
15. trunk control[tiab]
16. physiotherap*[tiab]
17. physical therap*[tiab]
18. rehabil*[tiab]
19. 19. #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR # 13 OR # 14 OR #15 OR #16 OR # 17 OR #18
20. #5 AND #19 Filters: Randomized controlled trials; Humans; November 2012 – October 2017

Appendix 2

Abbreviation	Explanation		Abbreviation	Explanation
CT	Conventional therapy		‘	Minutes
AT	Additional therapy		FIST	Function in sitting test
E	Experimental group		PVF	Peak vertical force
C	Control group		%BW	Percentage body weight
pTENS	Placebo TENS		SP	Sway path
mFRT (F)	Forward reach		SA	Sway area
mFRT (N)	Reach to non-affected side		SAP	Sway average speed
mFRT (A)	Reach to affected side		COP VA	Velocity average of center of pressure
I	Ischemic stroke		COP TPL	Total path length of center of pressure
H	Hemorrhagic stroke		MAS siting	Motor assessment scale sit subscale
M	Male		GRF	Ground reaction force
F	Female		TRE	Trunk reposition error
m	months		ML	Medial-lateral speed
d	days		AP	Anterior-posterior speed
wk	weeks		VM	Velocity moment

Appendix 3

Study	Conventional therapy	Additional therapy (experimental condition)	Additional therapy (control condition)
Bae 2013[48]		Trunk stabilization exercises on an unstable support surface (physioball) for: Task-specific movement exercises of the upper and lower trunk in the supine and sitting positions. Cooling-down. Progression: reducing the base of support, increasing the lever arm, advancing the balance limits, or increasing the hold time.	Trunk stabilization exercises on a stable support surface for: Task-specific movement exercises of the upper and lower trunk in the supine and sitting positions. Cooling-down.
Büyükavci 2016[30]	Neurodevelopmental facilitation techniques and occupational therapy.	Trunk balance oriented circuit training while sitting in an armless chair in front of a table. Patients were asked to sit with their hips and knees flexed at 90 degrees, feet open and aligned with hips and soles of the feet fully touching the ground. The hemiparetic arm was rested on the leg or positioned in an arm sling.	
Cabanas-Valdés 2016[39]	Mainly physiotherapy; tone facilitation, stretching, passive mobilization and ROM exercises for the hemiparetic side, walking between parallel bars and occupational therapy and nursing care.	The core stability exercises were selective, repetitive movements and involved tasks without resistance to improve strength, endurance, and coordination of the core.	
Cabanas-Valdés 2017[29]	Patient-specific: Physiotherapy: tone facilitation, stretching, passive mobilization, range-of-motion exercises for the hemiparetic side, etc. walking between parallel bars occupational therapy nursing care.	Activities of the trunk integrated in postural control and task-directed movement were performed + core stability exercises. The program was divided into three steps based on the level of difficulty: 1. The exercises were performed in a supine position on a plinth or bed. 2. The exercises were performed in a sitting position on a stable surface. 3. The exercises were performed in sitting position on a physioball.	Activities of the trunk integrated in postural control and task-directed movement were performed.
Chan 2015[42]		TENS + TRTT: received TENS simultaneously with the TRTT at home under the instruction of a physical therapist. Each subject in the TENS + TRTT and placebo-TENS + TRTT groups was provided with their own model ITO 120Z dual channel TENS stimulator. Pairs of electrodes were placed on the skin over the latissimus dorsi (lateral to T9 over the muscle belly) and the external abdominus obliquus (aligned 45° to the vertical, 15 cm lateral to the umbilicus, anterior to the axillary line) on the affected side. High frequency TENS (frequency 100 Hz; pulse width 0.2 ms) was used. The intensity of stimulation was set at twice the	The subjects in the control group did not receive any active training except health education on measuring their blood pressure and monitoring the incidence of falls.

		sensory threshold (the minimum intensity the subject could feel), which was barely below the motor threshold. TTE + sham TENS: For the placebo stimulation, the electrical circuitry inside the TENS machine had been disconnected. An LED light blinked when the stimulator was switched on, but no electric current was delivered to the subject. The physical therapist told all subjects before the intervention that "You might or might not feel any sensation or muscle contraction during the stimulation."	
Choi 2014[32]	Task-oriented training in sitting position.	Whole Body Vibration during task-oriented training. Frequency: 15-22Hz.Amplitude: 0-5.8mm. 4 tasks: 1. Sitting alone at a table and correcting body alignment. 2. Reaching in different directions for objects located beyond arm's length using the nonparetic side. 3. Reaching in different directions for objects located beyond arm's length using the paretic side. 4. A bilateral reaching task, such as throwing a ball, lifting a box, and inserting a ring.	
Dean 1997[15]		Standardized training programs: to improve sitting balance and involved emphasis on appropriate loading of the affected leg while practicing reaching tasks using the unaffected hand to grasp objects located beyond arm's length Variation: 1. Under varied conditions 2. Changing location of object; distance and direction 3. Seat height, movement speed, object weight, and extent of thigh support on the seat 4. Increasing the number of repetitions and complexity of the tasks	The control group had sham training that incorporated the performance of cognitive-manipulative tasks while seated at a table. Subjects were seated in a chair with arm and back supports and the forearms resting on a table. They performed manipulative tasks using the unaffected hand over small distances. Manipulative tasks using the unaffected hand over small distances (less than 50% of arm length). Variation: increasing the repetitions and cognitive difficulty of the tasks
Dean 2007[33]	During the training period participants in both groups received all regular physiotherapy intervention other than training to improve sitting. All participants continued to attend other multidisciplinary rehabilitation services.	Sitting training protocol designed by Dean and Shepherd (1997)[42]. It was designed to improve sitting by reaching beyond arm's length using the unaffected hand whilst focusing on: (1) smooth co- ordinated motion of the trunk and arm to get the hand to the object; (2) appropriate loading of the affected foot; and (3) preventing the use of maladaptive strategies such as widening the base of support. While reaching beyond arm's length, reach distance, direction, thigh support, seat height, and task were varied systematically. Training was progressed over the 2-week period by increasing the reach distance and the number of repetitions.	A sham sitting training protocol designed to improve attention (Dean and Shepherd 1997). This training involved participants completing a series of 11 cognitive-manipulative tasks. Participants were seated at a table, well supported in a chair with back and armrests, with their forearms resting on the table. The workspace was confined so that reach distance was less than 50% of arm's length which minimised perturbations to balance. Training was progressed over the 2-week period by increasing the number of repetitions and cognitive difficulty of the cognitive-manipulative tasks. Therefore, this training was sham sitting training because the perturbations to balance were minimal and were unlikely to lead to improvements in sitting.

Dell'Uomo 2017[27]	Neurorehabilitation: facilitation of movements on the paretic side, exercises to decrease spasticity exercises to improve balance, standing, sitting, transferring and walking.	Additional: specific training for functional re-education of shoulder, passive mobilization of the scapula, task-oriented exercises of the shoulder in open and closed kinetic chain, scapular stability and dynamic exercises and proprioceptive stimulation.	Non-specific arm/trunk rehabilitation. Composed of exercises for upper hemiparetic limb, in supine or sitting position, and postural changes training.
Fujino 2015[50]	Patient specific and consists of usual physiotherapy, occupational therapy, neuropsychological therapy, speech therapy, and nursing care. Usual physiotherapy includes mobilization, sit to stand training, gait training and ADL training.	Patients received standardized lateral sitting training. The experimental group sat without leg support on a platform tilted 10u to the paretic side in the frontal plane. Patients asked to move their trunk laterally from the paretic side to the nonparetic side. After lateral movement of the trunk to a vertical visual target, patients were tilted (back) to the paretic side as much as possible under their own control. Patients got instructed to gaze at a visual clue and to refrain from rotating their trunk.	Patients received standardized lateral sitting training. The controls sat on a horizontal platform. Patients asked to move their trunk laterally from the paretic side to the nonparetic side. After lateral movement of the trunk to a vertical visual target, patients were tilted (back) to the paretic side as much as possible under their own control. Patients got instructed to gaze at a visual clue and to refrain from rotating their trunk.
Haruyama 2017[43]	Conventional multidisciplinary stroke rehabilitation program, is patient specific and consists mainly of physical therapy, occupational therapy, speech therapy and nursing care.	The core stability training consisted of ADIM as a selective contraction of TrA, selective movements of the pelvis, and pelvic movements with ADIM. For ADIM, subjects were instructed to draw the lower part of the abdomen up and in toward the spine, without movement of the trunk or pelvis while continuing to breathe normally. ADIM was performed in a crook lying position, then in a sitting position. Pelvic control exercises were composed from the following three planes of movement: anterior-posterior tilt; lateral lift; and transverse rotation.	
Ibrahimi 2010[26]	Strengthing and stretching exercise for upper and lower limb. It was in form of 1-3 sets of 10-15 repetitions in each session.	Sitting balance training under varied sensory input. For training in sitting a chair without backrest was selected for each subject and the height of chair was standardized for each subject. Then the chair was placed at a distance of 140% of arm length and line was marked with the help of adhesive tape on wall at 140% of arm length at shoulder level and the subject was asked to sit on chair. Varied sensory input was provided to the subject in form of air filled pillows below the buttock as well as feet. This air filled pillow provided the instability on which sitting balance training protocol was followed. In training protocol all subjects were asked to touch the marked line on wall in three directions forward, 45 degrees towards unaffected side and 45 degrees across the body towards affected side using unaffected hand.	Sitting balance training without varied sensory input. A chair without backrest was selected for each subject. The height of stool was standardized for each subject. Then the chair was placed at a distance of 140% of arm length and line was marked with the help of adhesive tape on wall at 140% of arm length which was at shoulder level and the subject was asked to sit on chair. In contrast to experimental group no instability was provided. There protocol consisted of the marked line on wall in three directions forward, 45 degrees towards unaffected side and 45 degrees across the body towards affected side using unaffected hand.
Jung 2014[28]	Patient specific and consisted physiotherapy including stretching, strengthening and stationary bicycle.	Subjects were instructed to shift their weight and touch the bar placed on both sides by elongating the trunk on the weight shifting side. Subjects were to hold the position for 10 seconds when they reached the target point by shifting weight, and then return to the starting position; this was counted as one trial. Each subject performed three sets of 10 trials, rest for 30-second break between each set, and a 1-minute break between each type of training.	

Jung, Cho 2016[49]		Trunk exercises included weight-shifting and arm flexion in the sitting position. During the weight shifting exercise, the subjects were instructed to sit with their arms folded and to shift their weights from midline to the right and left, as far as they could, and touch a bar placed on both sides. During the arm flexion exercise, the subjects were instructed to flex both their arms as high as they could on the balance pad. Exercises on an unstable surface.	Trunk exercises included weight-shifting and arm flexion in the sitting position. During the weight shifting exercise, the subjects were instructed to sit with their arms folded and to shift their weights from midline to the right and left, as far as they could, and touch a bar placed on both sides. During the arm flexion exercise, the subjects were instructed to flex both their arms as high as they could on a stable surface. Exercises on a stable surface.
Jung, Jung 2016[46]	Conventional exercise was performed using the neurodevelopmental treatment and motor relearning based in the Bobath technique, such as tone facilitation and a range of movement exercise.	WSE+TENS group: transcutaneous electrical nerve stimulation electrodes were attached over the ES and EO muscles on the affected side (two to three times the sensory threshold, 100 Hz; 200us) was applied to the muscle belly of the ES and EO using a TENS machine STP+ TENS sham group: Participated in weight shift training in a seated position. Electrodes were attached at the same location, but electrical stimulation was not applied.	Received stretching exercise on supine, prone and side lying position on limbs and trunk and stationary bicycle exercise for the same amount of time
Karthikbabu 2011[47]	Regular acute-phase physiotherapy treatment: Tone facilitation and range of movement exercises.	Trunk exercises on the physioball: Task specific movements of upper and lower part of the trunk Supine and sitting pos. Variation possibilities: 1. Reducing the base of support; 2. Increasing the lever arm; 3. Advancing the balance limits; 4. Increasing the hold time.	Trunk exercises on the plinth: Task specific movements of upper and lower part of the trunk in supine and sitting pos.
Kilinc 2016[45]		The treatment program was developed taking the functional limitations of the patients into account, and consisted of seven trunk exercises according to the Bobath concept. These were: 1. stretching of the latissimus dorsi muscle 2. functional use and strengthening of the latissimus dorsi 3. functional strengthening of abdominal and oblique abdominal muscles 4. placing exercises in order to facilitate trunk extension 5. rotations and counter-rotations (right and left) of the hips with the trunk extended 6. training of lumbar spine stabilizers 7. functional reach of shoulder, anterior, right, and left sides.	Strengthening (trunk flexion–extension) and stretching exercises (stretching and elongation), mat activities (bridging), functional activities (weight transfer to from anterior to posterior and left to right), and range of motion exercises (trunk flexion, extension, left–right rotation, lateral flexion)
Ko (Ho Chun) 2016[25]	Standard Rehabilitation Program: Physiotherapy Occupational therapy If needed cognitive and speech therapy.	CMS group: Trunk muscle strengthening, Selective movements of the trunk muscle, Coordination. Carried out in supine, prone and lateral positions. tNMES group: 4 electrodes on thoracic and lumbar erector spinae, 30-70 mA, 250ms, 35 Hz, 10 sec, 12 sec pause In sitting position. Patient could feel contraction, but no pain or tiredness.	

		Combination group: CMS program and received tNMES combined while on their back.	
Kumar 2011[34]	Multidisciplinary stroke rehabilitation program. This program is patient specific with main emphasis on the neurodevelopmental concept and on motor learning strategies.	This additional exercise consisted of selective movements of the upper and lower part of the trunk in supine and sitting. Bridging, unilateral pelvic bridging, trunk rotations, static sitting balance, trunk flexion, trunk lateral flexion, trunk rotation, weight shifts, forward reach, lateral reach, perturbations	
Lee 2012[35]	The physical and occupational therapists carried out the general exercise program which consisted of Brunnstrom motion therapy, Bobath neurological development therapy, and proprioceptive neuromuscular facilitation. The physical therapist spent 10 minutes each conducting: flexibility training, resistance exercise for muscle strengthening, and pelvic tilting exercise focused on trunk control ability. The occupational therapist carried out activities of daily living training focused on functional activities for 30 minutes.	The dual motor task training group performed 5 minutes of warm-up exercise before the start of training such as raising the upper extremities, trunk flexion and rotation for range of motion and flexibility. The therapist supported the patients if they couldn't perform the movements actively. The dual motor task training was performed using the upper extremities while sitting on unstable ground to stimulate active balance. A 50 cm diameter disk was used as unstable ground. Subjects sat on the disk with their knee and hip joints flexed at 90° and with their feet touching the ground. The training was administered in three steps, 2 weeks for each step, for a total of 6 weeks to motivate patients. Patients moved a cup forward and from the coronal plane to the diagonal side while keeping balance in the sitting position on unstable ground for the first step. For the second step, patients performed targeting with a ball and tossing a balloon. In the third step, patients did fishing and played badminton while keeping balance in the sitting position on unstable ground. Each step was performed for 12 minutes and one minute of resting time was given between each step.	
Lee 2016[38]	Physical therapy: gait training and lower limb strengthening, based on the NDT concept. Occupational therapy Functional Electrical Stimulation (FES): upper and lower limb.	Canoe game-based VR training: If needed gripgloves were used. Adjusting trunk to maintain balance and paddling with upper limbs. 3 session modes: 1. A free-practice mode for familiarization and warm-up. 2. A timed-run mode, designed to achieve a personal record of the distance travelled in a limited time period. 3. A competition mode designed to improve motivation through competition with the caregiver or therapist.	
Saeys 2012[41]	Multidisciplinary conventional physical and occupational therapy as provided by the rehabilitation staff, mainly focused on neurodevelopmental treatments. In clinical practice, activities of the trunk are integrated in postural control and task directed movement.	Improve truncal function: trunk muscle strength, coordination, selective movements of the trunk, in sitting or supine position	Passive mobilization of the upper limb and transcutaneous electrical nerve stimulation of the hemiplegic shoulder while supine.
Sharma 2017[24]		They were asked to recognize their neutral spine position that is midrange between flexion and extension. In the first stage the participants were taught to activate abdominal wall musculature. Participants were requested to perform	Pelvic PNF along with trunk flexibility exercises, which consisted task-specific exercises of the upper and lower part of the trunk. The exercises were performed both in the supine and in sitting positions.

		abdominal muscle contractions with verbal commands. Once the patient mastered the technique of abdominal bracing progression was made to other core stability exercises. Participants were then positioned in quadruped position and asked to lift alternate arms, gradually progressing to alternate leg lifts and alternate arm/leg raises to activate multifidus. This was followed by side bridges (side plank) exercise for activation of quadratus lumborum and obliques. The participants were then asked to perform trunk curls in crook lying, asked to lift their upper trunk slightly (15°) from the plinth, hold the position for 5 sec. The progression of exercises was done once the patient was able to perform 30 repetition of each exercise with 8-sec hold. The participants were told to maintain normal diaphragmatic breathing throughout the intervention.	
Shin 2016[31]	The conventional rehabilitation program consisted of personalized physical and occupational therapy and electrical stimulation therapy. Physical therapy consisted of neurodevelopmental and proprioceptive neuromuscular facilitation treatments.	Visual feedback trunk control training using a smartphone based trunk control training. Participants performed the given task by moving their trunk in various directions as required by the smartphone applications. The participants were provided visual auditory feedback information regarding their trunk movements by the smartphone applications.	
Verheyden 2009[40]	Rehabilitation Program: Physiotherapy Occupational therapy Nursing care If needed speech and neuropsychological therapy.	Selective movements of the upper and lower part of the trunk in supine and sitting.	
Yoo 2010[44]	Neurodevelopmental technique of physical therapy + walking + occupational therapy.	Core strengthening program: Deep breathing + exercises 9 core strengthening methods 3 steps based on level of difficulty: 1. Trunk bracing, bridge exercise, segmental rotation 2. Dead bug, hamstring curls, crossed extension 3. Side bridge, belly blaster, bird dog Each step maintained at 6-10 sec, 3 times.	