Title: The effectiveness of physiotherapy sitting balance treatments on sitting balance outcomes in early sub-acute stroke. A systematic review and meta-analysis.

Abstract

Background: Difficulties with sitting balance are common after stroke. The ability to sit unsupported is imperative for many daily tasks and correlated to more positive outcomes. There is limited research on "sitting balance" therapeutic interventions and their impact. This systematic review and meta-analysis aims to investigate the effectiveness of physiotherapy sitting balance treatments on sitting balance outcomes in people up to 3-months post-stroke.

Methods: The PRISMA checklist was followed and the review registered on PROSPERO. Seven electronic databases were searched to October 2023 (updated in January 2025) for studies comparing treatments focussing on sitting balance in adults who had suffered a cerebral stroke in the last three months. Studies were included if treatment was predominantly completed in sitting postures and reported sitting balance outcomes.

Studies were assessed for eligibility, and data extraction and risk of bias was completed by two independent reviewers.

Results: Data from 16 studies (623 participants) was synthesised narratively. Sitting balance interventions were classified into four main categories: weight shift and reaching; core stability exercises; environmental modifications; and task practice. A random effects meta-analysis conducted on eight studies (342 participants) revealed interventions to be beneficial for sitting balance (primary outcome: mean difference Trunk Impairment Scale 3.02; 95% confidence interval 2.19 to 3.86). Four studies demonstrated low risk of bias; and four showed some concerns.

Conclusions: The current sitting balance treatments offered to early sub-acute stroke patients show significant improvements in sitting balance primary outcome. Sitting balance treatments can be categorised into four sub-types, helping to standardise clinical application and ensure consistency in future research.

KEYWORDS: Physiotherapy, sitting balance, stroke.

PROSPERO: CRD42023444050

Contribution of the research:

Sitting balance impairment is significantly improved with therapy interventions completed in sitting.

Four main categories of sitting balance treatments have been researched in the subacute stroke population.

Introduction

Stroke is a common neurological condition caused by infarct or haemorrhage in the brain, leading to subsequent mild to severe disability[1]. It is reported that balance is affected in up to 80% of people post-stroke[2], with around 20% not regaining independent sitting during their hospitalisation[3]. Sitting balance is a necessity for many daily activities[4]. The ability to sit is a prognostic factor for longer-term mobility outcomes[5,6,7].

Balance involves three key sensory inputs: vision, sensation and vestibular; which integrate within the brain to coordinate the motor control output. Deficits within these systems cause impaired sitting balance, impacting on the ability to complete daily activities in sitting. Recent stroke clinical guidelines[8] recommend progressive balance training and repetitive task practice to treat impaired balance, combining sitting, standing and walking balance.

Sitting balance and tasks in sitting are currently a large component of stroke rehabilitation, especially in the earlier stages post stroke when people are often under the care of specialist stroke teams. Positive gains from seated exercises on balance and mobility outcomes have been demonstrated in a recent meta-analysis[9]. Seven studies were included, using chair-based interventions in adults living with stroke who were mostly in the chronic phase after onset. A recent Cochrane review[10] of 68 studies (2585 participants) comparing trunk training versus non-dose-matched or dose-matched control therapy demonstrated significant improvements in activities of daily living as a primary outcome, as well as improvements in standing balance and trunk function, with more significant results in the non-dose matched comparisons. Whilst this review demonstrated positive outcomes as a result of trunk training, included studies were generally of very low to low quality and little research was found to have been done in the acute and sub-acute stages after stroke onset. This is a critical time period for targeted rehabilitation to optimise opportunity for recovery; and sitting balance ability in this period has been shown to be important for prediction of recovery[5]. It remains unclear which treatments might best be used in clinical practice, to support recovery of this important function during the early stages of rehabilitation.

This systematic review and meta-analysis aimed to investigate the effectiveness of physiotherapy sitting balance treatments on sitting balance outcomes in people up to three months post-stroke (early subacute phase[11]). The primary outcome of sitting balance impairment, and secondary outcomes of sitting balance function, are assessed, in line with expert recommendations on sitting balance outcome measurement in stroke research[12].

It also aims to categorise types of sitting balance intervention from the current research, in order to enhance clinical potential clinical application.

Methods

The protocol for this systematic review was prospectively registered in July 2023 with the PROSPERO database (CRD42023444050) and is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement[13].

Studies were included in the review if:

(1) they were experimental design, with a control arm;

(2) they included people aged 18 years and older who had experienced a stroke, and who were within the early sub-acute (three months or less) stroke period;

(3) sitting balance treatment intervention (treatment predominantly in sitting posture) was main experimental treatment;

(4) they reported sitting balance outcome measurements.

Studies were excluded from the review if:

(1) they were of a design other than experimental;

(2) the primary outcome measurement focussed on standing balance or gait;
(3) interventions were primarily completed in postures other than sitting;
(4) they reported other neurological conditions with stroke;
(5) participants were in the later phase (more than three months) post-stroke, or had more than one previous stroke.

Search strategy, study selection and data extraction

The electronic databases MEDLINE, CINAHL, EMCARE, EMBASE, SCOPUS, WEB of SCIENCE and AMED were systematically searched in October 2023, and updated in January 2025, by a medical librarian using a combination of keyword search terms around the constructs of sitting, balance, physiotherapy and stroke (appendix 1). Duplicates were removed. Studies were assessed by two independent reviewers (RR, JHP or KW) using specific eligibility criteria, initially by title and abstract, then full text, using the Rayyan software[14]. A third reviewer (JHP or KW) was available for disagreement resolution, if required. Reference lists of included papers were checked. Information on the participant demographics, intervention, controls, and main sitting balance outcomes in the studies were extracted independently by two reviewers (RR, and either JHP or KW).

Risk of Bias Assessment

The bias of individual studies was assessed by two reviewers (RR, and either JHP or KW) independently using the Cochrane Risk of Bias tool (ROB-2 tool)[15]. If discrepancies occurred, a third reviewer (JHP or KW) decided following their own assessment.

Statistical Analysis

A meta-analysis was conducted based on the primary outcome of measurement of sitting balance impairment. A secondary meta-analysis was conducted on the secondary outcome of sitting balance activity/function.

For both outcomes, random effects meta-analyses were constructed using the DerSimionian and Laird model[16]. This model assumes that the individual studies represent a random sample from a population of studies with a mean treatment effect about which individual study effects vary. Random effects models were chosen for the meta-analyses to reflect recognised clinical and methodological heterogeneity across included studies with respect to the outcome measures. A 95% confidence interval of the approximate predictive distribution of a future trial, based on the extent of heterogeneity, was included in the meta-analysis of the primary outcome.

The meta-analysis of the primary outcome was based on pooled unstandardised mean differences, as all studies utilised the same outcome measured on the same scale. The secondary meta-analysis was based on consideration of a pooled standardised mean difference, as not all studies used the same instrument to measure the outcome of interest.

Effects were calculated based on intervention effect minus control treatment effect; with precision assessed via associated 95% confidence intervals (CIs). Analyses were based on summary statistics of post-test scores in both groups (sample size, mean and standard deviation). Where not reported directly, standard deviations were calculated from reported confidence intervals.

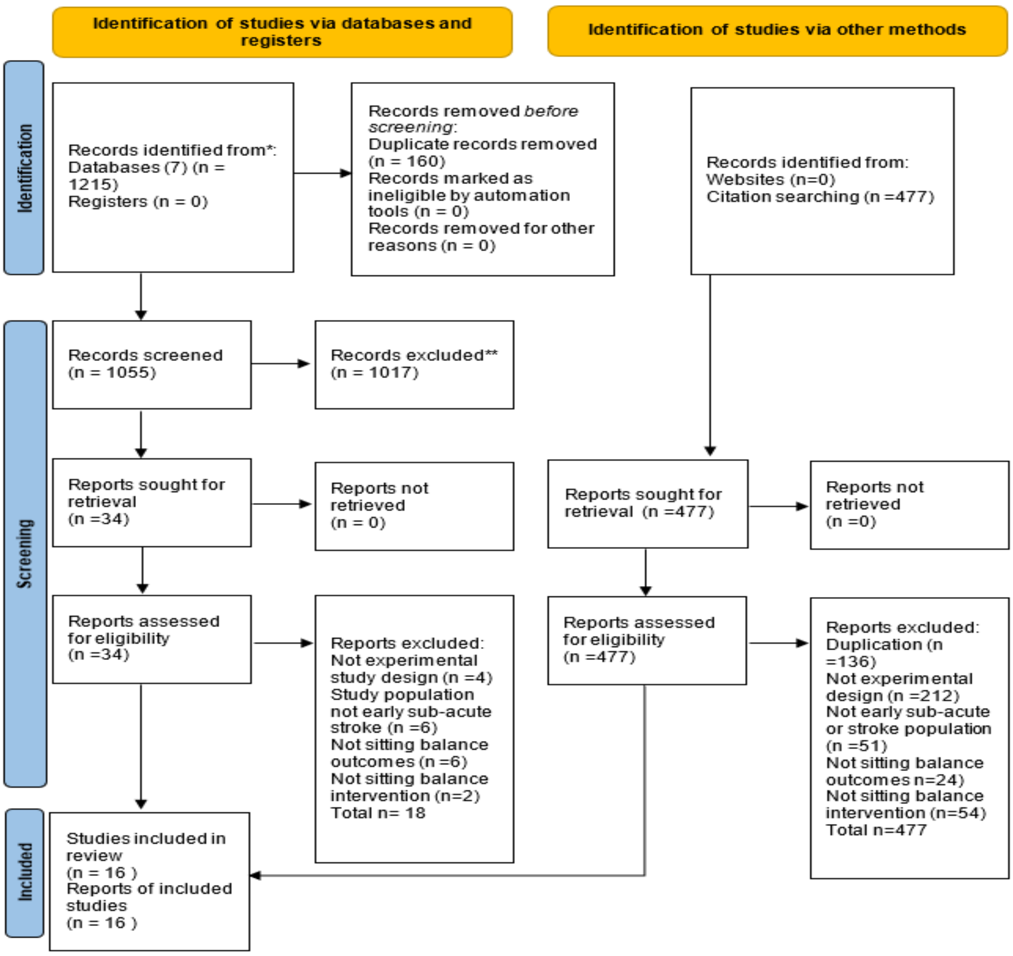
Forest plots were conducted for both meta-analyses, reporting the synthesised estimate, and associated 95% CI, and a Z-test for the standardised mean difference. Heterogeneity statistics were also reported, including findings from a test for heterogeneity, the I^2 statistic and the τ^2 statistic (an estimate of between-study variance). Statistical significance was reported at the 5% significance level.

Sensitivity analyses were conducted on the meta-analyses of the primary outcome to assess the robustness of the derived estimates. Funnel plots were proposed for the meta-analysis of the primary outcome to detect small study effect-related bias but were not constructed due to a paucity of included studies. No subgroup analyses were proposed or conducted.

Results

The combined databases searched identified 1299 papers. After removal of duplicates, 1055 trials were screened by title and abstract. This process identified 34 full-text articles for screening; of which 16 met the inclusion criteria and were included in the review. Figure 1 details the PRISMA flow diagram of the search process. All citations of the included studies were reviewed for relevant studies, but no new additional studies were identified.

Figure 1 PRISMA flow diagram



Data was extracted and analysed using a standardised template for the 16 included studies (Table 1).

Study	Study Design; Country	Participant characteristics Sample size; male: female; right: left stroke; Experimental group (E) : comparison (C); E:C mean age (SD); sample clinical characteristics	Experimental condition (CATEGORY)	Comparison	Sitting balance outcome measures and results (p-value)	Result summary
Murkel and Merholz, 2014[17]	RCT Germany	20 M:F 11:9; R:L 11:9; E:C 10:10; Mean age (SD): 71.67+/-9.94: 72.7 +/- 4.62 Trunk Control Test>48	Single session External focus, shift as much weight sidewards to an external point. **WEIGHT SHIFT and REACHING**	Single session, Internal focus, maximal shift weight sideways.	Lateral weight shift distance. External focus group greater difference of lateral body weight shift (8.7 cm ± 2.6 versus 4.5 cm ± 3.3; P = 0.006).	Both groups showed improved lateral body weight shift.
Pollock et al, 2002[18]	Pilot RCT United Kingdom	28 M:F 12:16 R:L 17:11 E:C 9:19 Mean age: 68.4 +/- 13.4: 73.1 +/- 10.3 Only anterior strokes (no POCS)	Independent practice session of sitting reaching tasks **WEIGHT SHIFT and REACHING**	Conventional therapy	Force plate weight transfer and symmetry. No significant differences between the two groups (p > 0.05)	Both groups showed some improvement in max weight transfer and better weight symmetry distribution in experimental group.
Saeys et al, 2012 [19] **	RCT Belgium	33 M:F 16:17 R:L 17:16 E:C 18:15 Mean age: 61.9+/-13.8: 61.07 +/- 9 Berg Balance score>25./56	Sitting muscle strengthening, task practice **CORE STABILITY, TASK PRACTICE, REACHING AND WEIGHT SHIFT**	UL rehabilitation exercises	Trunk Impairment scale. A treatment effect was found for the experimental group on the TIS (P < .001)	Improved dynamic sitting balance both groups, better in experimental group.
Sheehy et al, 2020 [20] *	RCT America	76 M:F 42:27 R:L 42:27 E:C 38:38 Mean age: 64.9 +/-15.8; 64.7 +/-15.2	Virtual Reality reaching exercises **ENVIRONMENTAL, REACHING AND WEIGHT SHIFT**	Virtual reality - minimal trunk or UL movement	Function in sitting test, Pre/post differences for FIST were 3.4 ([CI] 0.5;6.3) for the experimental group; 5.3 (2.9;7.7) for the control group, no difference between groups p>0.006)	Both groups improved, control group more.
Verheyden et al, 2009[21] **	Pilot RCT Belgium	33 M:F 20:13 R:L 17:16 E:C 17:16 Mean age: 52 +/-11; 62 +/- 13 Baseline Trunk Impairment scale 14-16	Supine / sitting trunk control exercises **CORE STABILITY**	Conventional therapy	Trunk Impairment scale Dynamic sitting balance subscale showed significant improvements (P = .002), all others no significant different between groups.	Improved dynamic trunk impairment in intervention.
Cabanas-Valdes et al, 2016[22] *,**	RCT Spain	80 M:F 40:40 R:L 45:35 E:C 40:40 Mean age: 75.69 +/-9.4; 74.92 +/- 10.7 Baseline Trunk Impairment scale 3-4	15 mins additional core stability training **CORE STABILITY**	Conventional therapy	Trunk Impairment scale, FIST. Experimental group showed statistically significant differences for all of the total scale scores (P<0.05).	Greater improvements in intervention group for all outcome measures.
Dean et al, 2007[23]	RCT United Kingdom	12 M:F 6:6 R:L 8:4 E:C 9:3 Mean age: 60+/-7; 74 +/-12 Two week daily training.	Sitting training reaching out of base of support **WEIGHT SHIFT and REACHING**	Upper limb training in base of support	Maximum reach and speed of reach. The experimental group had increased their maximum reach distance by 0.17 m (95% CI 0.12 to 0.21), decreased their movement time by 0.5 s (95% CI –0.8 to –0.2).	Greater improvements in intervention group for sitting ability, better reach distance/
Fujino et al, 2016[24] *	RCT Japan	43 M:F 21:9 R:L 10:20 E:C 23:20 Mean age: 67.9 +/-7.8; 64.4 +/- 7.5	Sitting on plinth tilted 10 degrees, lateral weight shift **ENVIRONMENTAL, WEIGHT SHIFT and REACHING**	lateral weight shift on plinth	Trunk control test, lateral weight shift. Significant differences in experimental group compared to control in the TCT (P<0.05)	Trunk control test showed significant difference in intervention group.
Howe et al, 2005[25] *	RCT	35 M:F 18:17	Seated reaching **WEIGHT SHIFT and REACHING**	Conventional therapy	Lateral reach distance, and time taken to return to sit position.	No significant difference between groups except

	United Kingdom	R:L 20:15 E:C 17:18 Mean age: 71.5 +/- 10.2; 70.7 +/- 7.2			Time taken to return to quiet sit in intervention group improved significantly (p=0.01).	time returning to sit position.
Khallaf, 2020 [26] **	RCT Egypt	34 M:F 17:17 R:L unknown E:C 17:17 Mean age: 58.76 ± 3.51; 56.71 ± 3.74	Task practice **TASK PRACTICE**	Conventional therapy	Trunk Impairment scale improved significantly in experimental group (p=0.001)	Both groups improved, better trends in intervention.
Lee et al, 2017[27] **	RCT Korea	30 M:F 15:15 R:L 13:17 E:C 15:15 Mean age: 59.1±16.9; 64.4±14.8 Pusher syndrome, Trunk Impairment scale<2	Whole body vibration **ENVIRONMENTAL**	Conventional therapy	Trunk Impairment scale No significant difference between groups (p=0.76) but both groups sitting improved on all measures.	Both groups improved significantly.
Lee, Lee and Song, 2018[28] *	RCT Korea	31 M:F 18:12 R:L 19:11 E:C 16:15 Mean age: 61.80±6.80; 61.33±8.44 Baseline Trunk Impairment scale 6-13	Virtual reality in sitting **ENVIRONMENTAL**	Conventional therapy	Functional reach in sitting. Postural balance were significantly improved in the experimental group when compared with the control (p<0.05).	Significant improvements both groups, greater in intervention.
Lee et al, 2020[29]	RCT Taiwan	35 M:F 19:16 R:L 13:22 E:C 18:17 Mean age: 60.2 ± 11.7; 62.4 ± 13.3 All could sit without support >30secs	Unstable surface trunk training **ENVIRONMENTAL**	Upper limb + conventional therapy	Sitting with and without foot support sway, Trunk impairment scale. Experimental group had significantly greater forward leaning (p=0.001), higher Trunk Impairment Scale total score (p=0.035)	Significant improvements both groups, greater in intervention.
Kumar et al, 2010[30] **	Pilot RCT India	20 M:F 10:10 R:L 11:9 E:C 10:10 Mean age: 59.5 ± 12.09: 57.8± 13.49 All could sit without support >30secs	Additional trunk training **CORE STABILITY**	Conventional therapy	Trunk Impairment scale, statistical significant improvement in intervention group compared to control p<0.05.	Both groups improved, statistical significance between groups in favour of intervention
Kathikbabu et al, 2011[31] **	Pilot RCT India	30 M:F 17:13 R:L 11:19 E:C 15:15 Mean age: 59.8 +/- 10.8; 55 +/-6.5 All could sit without support >30secs	Gym ball (unstable surface) **ENVIRONMENTAL, CORE STABILITY**	Conventional therapy on plinth	Trunk Impairment scale. Experimental group improved more significantly than the control group (<0.05)	Both groups improved, statistically significant improvements in intervention group.
Cabanas-Valdes et al., 2025[32] *,**	RCT Spain	83 M:F 57:30 R:L 41:46 E:C 40:43 Mean age: 71.38 +/-11.6; 69.9 +/-15.2 Baseline trunk impairment scale <10	30 mins core stability exercises and conventional therapy **CORE STABILITY**	Conventional therapy	Trunk Impairment scale Significant differences between groups were shown (favouring intervention) in dynamic sitting balance (p<0.001), trunk coordination/function (p=0.003)	Both groups improved, greater improvements in intervention group.

**=studies included in primary meta-analysis, *=studies included in secondary meta-analysis

Table 1: Study sitting balance intervention and comparison characteristics

Study, intervention and comparison groups

Four studies[18,21,30,31] were pilot randomised controlled trials (RCT), and all others were RCTs. Publications dated from 2007 to 2025, with eight from Europe[17,18,19,21,22,23,25,32] and eight from the rest of the world. Intervention versus control group numbers, right compared to left strokes, gender and age (median age 60-70 years) were all approximately equally split. Lee et al[27] only used participants fitting "pusher syndrome" classifications. All study participants were within three months post-stroke, with seven studies predominantly assessing under one-month post-stroke[22,24,26,27,30,31,32]. No studies were in the acute timeframe of under seven days post-stroke. Study duration and dose of interventions varied. Minimum dose was one extra session[17], and with a maximum of 10 hours additional therapy over 6 weeks[30]. Nine studies were dose-matched[17,18,19, 20,25,26,27,30,32].

Sitting balance interventions fitted four key categories: weight shift and reaching[17,18,23,25], core stability exercise[21,22,30,32], task practice[19,26], and environmental modifications; which included whole body vibration[27], virtual reality[20,28], tilted plinth[24] and an unstable surfaces[29,31]. Cross-over between weight shift and task practice was reported in Pollock et al [18]. Comparison group treatment was conventional therapy without added treatment in eleven studies[18,21,22,24-28,30,31,32], conventional therapy with added treatment in two studies[19,29], and an alternate sitting balance treatment in three studies[17,20,23].

Study Quality

The Cochrane Risk of Bias (RoB-2) tool[15] was used to evaluate the 16 included studies. Nine studies showed overall low risk of bias. One study showed high risk of bias. Six studies showed some concerns. Agreement was obtained from the main reviewers in most cases: two cases required the intervention of the third reviewer. Most RoB concerns were around randomisation, measurements of outcome and the high concern was for missing data (Figure 2).

Study	D1	D2	D3	D4	D5	OVERALL
Murkel and Merholz, 2014	🟢	🟢	🟢	🟢	🟢	🟢
Pollock et al, 2002	🟢	🟢	🟡	🟡	🟢	🟡
Saeys et al, 2012 **	🟢	🟢	🟢	🟢	🟢	🟢
Sheehy et al, 2020 *	🟢	🟢	🔴	🟢	🟡	🔴
Verheyden et al, 2009 **	🟡	🟢	🟢	🟢	🟢	🟡
Calbanas-Valdes et al, 2016 *,**	🟢	🟢	🟢	🟢	🟢	🟢
Dean et al, 2007	🟡	🟡	🟢	🟢	🟢	🟡
Fujino et al, 2016 *	🟢	🟢	🟢	🟢	🟢	🟢
Howe et al, 2005 *	🟢	🟢	🟢	🟢	🟢	🟢
Khallaf, 2020 **	🟢	🟢	🟢	🟡	🟢	🟡
Lee et al, 2017 **	🟢	🟢	🟢	🟡	🟢	🟡
Lee, Lee and Song, 2018 *	🟢	🟢	🟢	🟢	🟢	🟢
Lee et al, 2020	🟢	🟢	🟢	🟢	🟢	🟢
Kumar et al, 2010 **	🟢	🟢	🟢	🟢	🟢	🟢
Kathikbabu et al, 2011 **	🟢	🟢	🟢	🟢	🟢	🟢

Cabanas-Valdes et al, 2025 *,**						

Low risk Some concerns High risk

**=studies included in primary meta-analysis, *=studies included in secondary meta-analysis

ROB-2 tool domains: D1- randomisation process, D2-deviation from intended intervention, D3-missing outcome data, 4-measurement of the outcome, 5- selection of reported result.

Figure 2: Risk of bias summary

Quantitative synthesis of primary outcome

Eight of the 15 included studies (342 participants in total; study size range 20 to 83 participants) featured in the quantitative analysis of the primary outcome. Eight studies[19,21,22,26,27,30,31,32] were included in the meta-analysis of the primary outcome (sitting balance impairment) reporting total scores of the trunk impairment scale (TIS Total). All reported mean differences favoured intervention methods: six studies reported a significant effect and two reporting a non-significant effect. No studies reported an effect in favour of control treatment.

The meta-analysis revealed that a synthesised estimate of the difference in mean sitting balance scores between intervention and control treatment was 3.02 (95% CI 2.19 to 3.86); i.e. favouring intervention methods. A Z-test revealed strong evidence for a non-zero effect (Z=7.09; p<0.001). A χ^2 test for heterogeneity revealed strong evidence for statistical heterogeneity ($\chi^2_{(7)}$=17.5; p=0.014). The I^2 statistic was 60.1%, indicating moderate levels of heterogeneity. The τ^2 statistic was 0.806. A 95% confidence interval for the approximate predictive distribution of a future trial was given by (0.59, 5.45). The data is summarised in a forest plot (Figure 3).

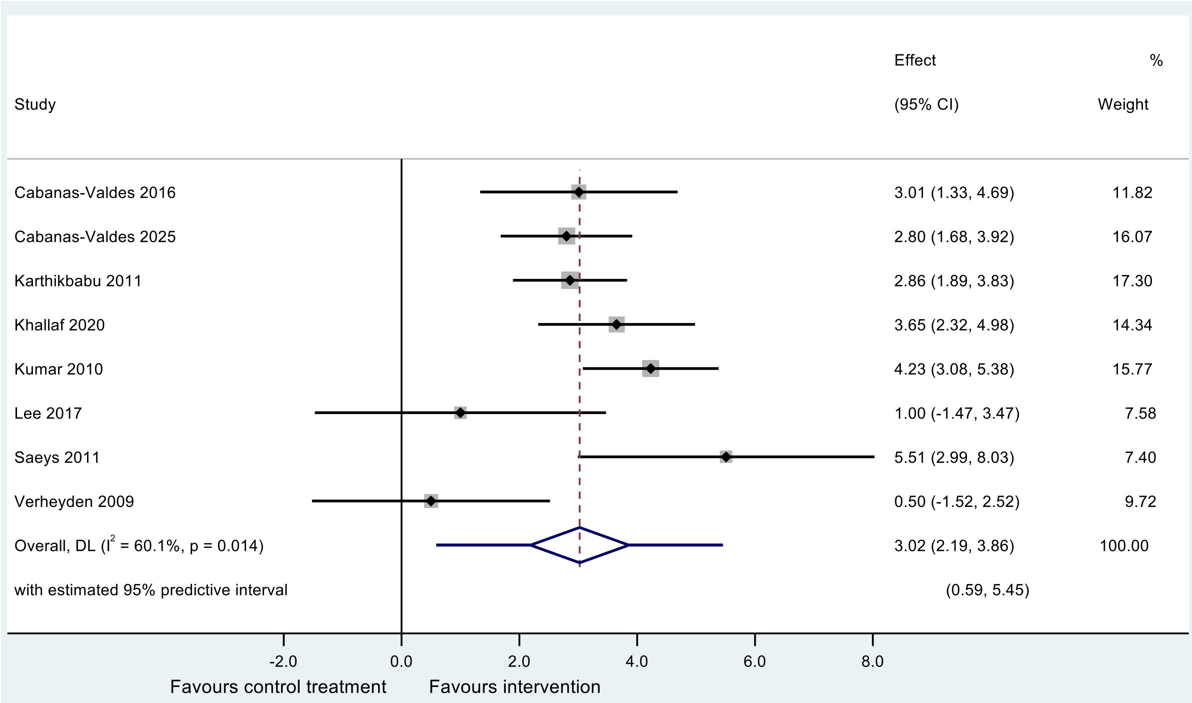


Figure 3: Forest plot for primary outcome (sitting balance, Trunk Impairment Scale (TIS) total)

A sensitivity analysis revealed no individual study to be exerting excessive influence on the meta-analysis, with all point estimates of the omitted analyses lying within the 95% CI associated with the estimate of the combined analysis. Estimates and associated CIs are plotted on an influence plot (Figure 4).

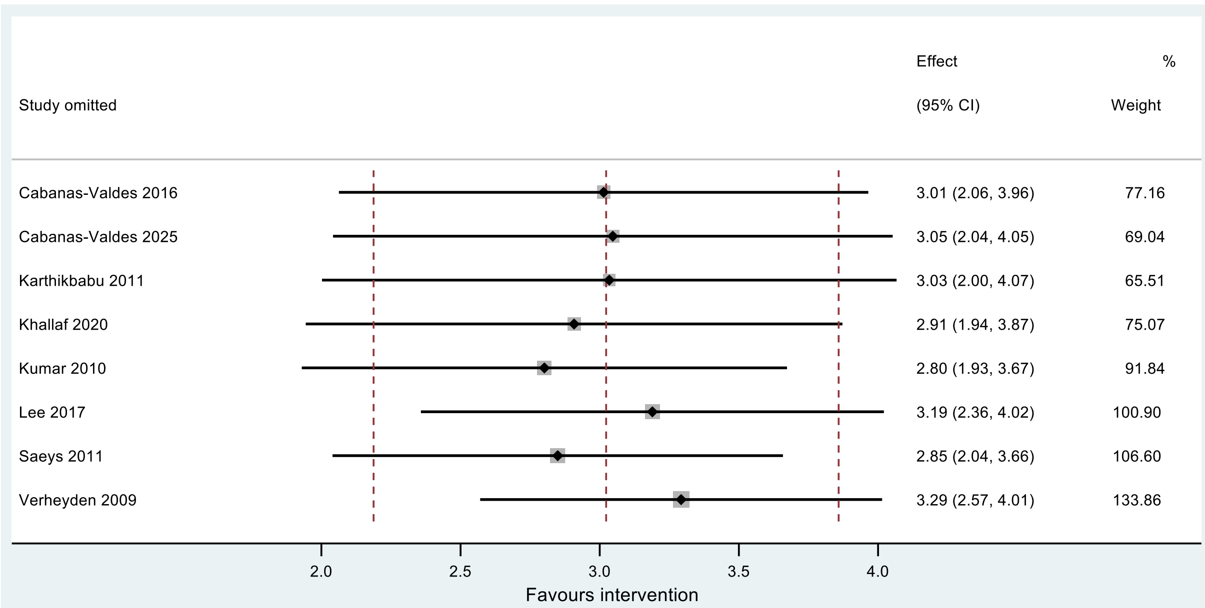


Figure 4: Influence plot for sitting balance outcome

Secondary outcome analysis

Six studies[20,22,24,25,28,32] were included in the meta-analysis of the secondary outcome (sitting balance function). Sitting balance functional tests included the Function in Sitting Test (FIST); the Trunk Control Test (TCT); the Lateral Reach Test and the Modified Forward Reach Test. In all these tests, higher scores represent higher levels of functionality. A meta-analysis revealed that a synthesised estimate of the standardised mean difference in scores from intervention and control treatment methods was 0.162 (95% CI -0.149 to 0.473); i.e. a non-significant effect favouring intervention methods. A *Z*-test revealed insufficient evidence for a non-zero effect (Z=1.02; p=0.308). A χ^2 test for heterogeneity revealed insufficient evidence for statistical heterogeneity ($\chi^2_{(5)}$=9.32; p=0.097). The I^2 statistic was 46.3%, indicating moderately low levels of heterogeneity. The τ^2 statistic was 0.0679. A 95% confidence interval for the approximate predictive distribution of a future trial was given by (-0.69, 1.01). The data is summarised in a forest plot (Figure 5).

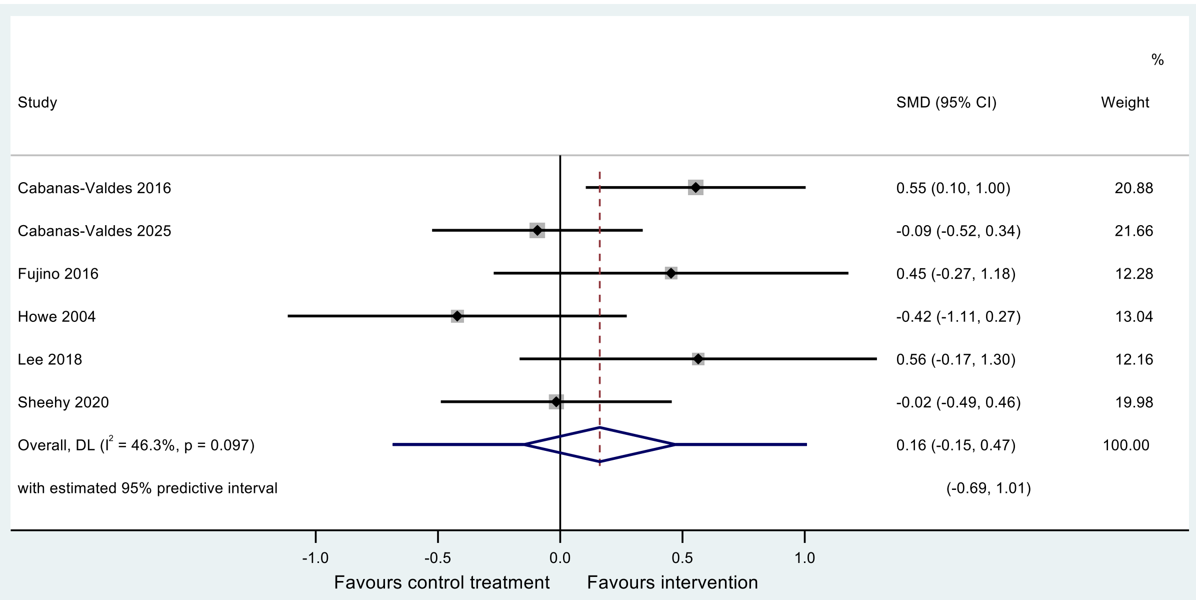


Figure 5 Forest plot for sitting balance function

A sensitivity analysis revealed no individual study to be exerting excessive influence on the meta-analysis, with all point estimates of the omitted analyses lying within the 95% CI associated with the estimate of the combined analysis. Estimates and associated CIs are plotted on an influence plot (Figure 6).

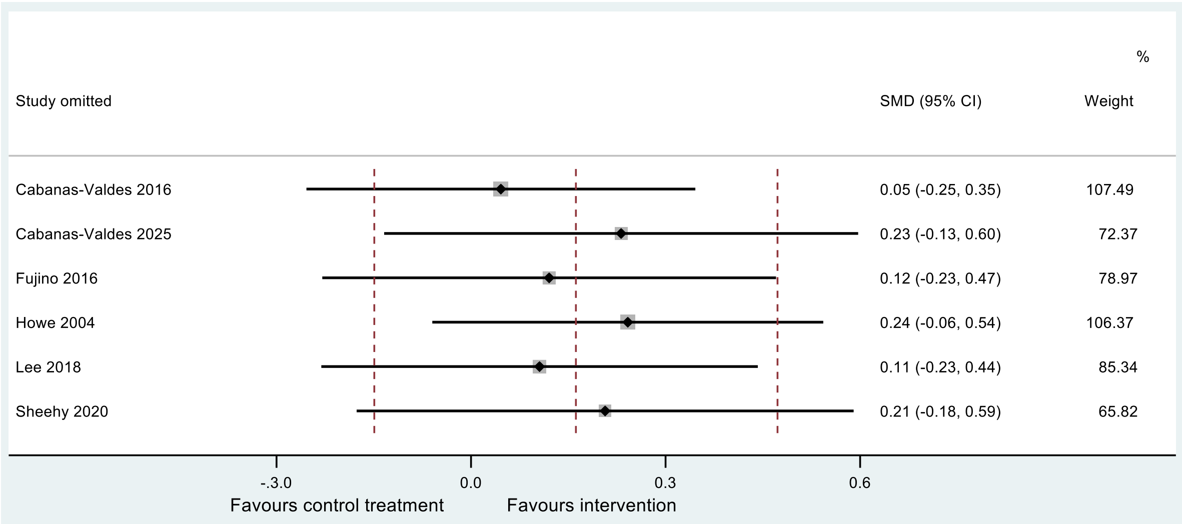


Figure 6: Influence plot for sitting balance function

Discussion

This systematic review and meta-analysis found significant improvements in sitting balance impairment, and positive, albeit non-significant trends in functional sitting outcomes, following sitting balance training interventions in patients in the early sub-acute phase post-stroke. Further, we were able to identify four main categories of sitting balance intervention from the current research: weight shift and reaching, core stability, task practice, and environmental modifications.

It is well-established that sitting balance is critical to participation in daily activities and is a known prognostic indicator of longer term outcomes after stroke. So, a deeper understanding of the effectiveness of sitting balance rehabilitation interventions is important. Our results show significant positive effects for interventions in sitting, compared to conventional therapy or a second treatment at a combination of non-dose[21,22,30] and dose-matched[19,26,27,31,32] for the primary sitting balance impairment outcome. This aligns with previous research on sitting exercises[9], trunk training[10] and training of sitting balance in a variety of postures[33] and expands knowledge of effect in the important time-window early after stroke.

Whilst studies differed in terms of specifics of interventions involved, we were able to meet our aim of categorising sitting treatments, in order to enhance clinical understanding of content of possible interventions. However, the review did not extend to examining effectiveness of specific content of interventions- further research should now examine which rehabilitation components and in what combination, might be optimal to enhance recovery.

Conventional treatments in the studies were not generally well described or consistent, detailing a variety of usual physiotherapy practice based on patient goals, muscle tone and strength improvements, range of movement exercises and task-oriented activities.

The link between more optimal sitting balance with better longer-term recovery outcomes is clear in existing evidence[5,6,7], but this review did not find any studies that reported outcomes beyond three months after stroke. These short-term follow-up durations of the included studies may offer some explanation for the lack of significance at sitting activity level. Expert guidelines recommend follow-up of at least six months[12].

This systematic review and meta-analysis focussed specifically on the effectiveness of sitting balance interventions in the sub-acute stroke population. It included six studies of participants within one-month post-stroke, previously identified as an under-researched population for sitting balance interventions[10]. This review strengthens the evidence we have available in this clinically important time frame.

Future work should focus on testing the effectiveness of the four proposed categories of sitting balance treatment, and for which patient characteristics and at what timepoints they might work optimally. Consideration of the sensory, motor and environmental components of balance should be investigated.

Strengths and limitations of this review

Whether sitting balance should be classified as an impairment or activity was considered carefully for this review, but in line with expert recommendation[12], impairment was agreed as the primary analysis. All studies in this review used the trunk impairment scale as their measure of sitting balance impairment, showing good consistency amongst stroke research on sitting balance impairment, and enabled use of unstandardised measures of effect in the meta-analysis. The sitting balance function outcomes were varied, but a standardised effect measures allowed for compatibility in the secondary meta-analysis. Use of the Stroke Recovery and Rehabilitation Roundtable (SRRR) balance outcome measure recommendations[12] in future research should help this further. The outcomes from the sensitivity analyses gives confidence that no single study excessively influenced either outcome. Eight papers in the primary meta-analysis and six in the secondary meta-analysis (including three studies appearing both the primary and secondary meta-analyses) utilised data from 474 participants under three months post-stroke, and the majority of papers included in the MAs were judged to be at low risk of bias.

Conclusions

Sitting balance treatment interventions improve sitting balance impairment in people with early sub-acute stroke, with demonstrable trends towards improving sitting function.

Weight-shift and reaching, task practice, core stability exercises and environmental modifications were all shown to be of benefit. Consensus of the four categories should be the focus of further work. Research is lacking in the acute phase post stroke, and for patients with more severe sitting balance impairment. Further research into patient preferences and optimisation of treatment implementation is warranted.

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Declaration of interest statement

The authors report there are no competing interests to declare.

References

1. Marshall, I., McKevitt, C., Wang, Y., Wafa, H., Skolarus, L., Sackley, C., Clarke, S., Hamidi, F., Stevens, E., Rudd, A., Rodgers, A., Wolfe, C. (2022) Stroke pathway –An evidence base for commissioning – An evidence review for NHS England and NHS Improvement, NIHR Open Research, 13257.1

2. Khan, F and Chevidikunnan, M.F. (2021) Prevalence of Balance Impairment and Factors Associated with balance among patients with Stroke. A cross-sectional retrospective case control study, 9, 320, HealthCare Published online: Mar 13 2021 (Accessed 17th Jan 2023) doi:10.3390/healthcare9030320

3. Fukata, K., Fujino, Y., Inoue, M., Inoue, M., Sekine, D., Tsutsumi, M. et al (2021) Factors Influencing Sitting Ability During the Acute Post-Stroke Phase: A Multicenter Prospective Cohort Study in Japan, Journal of Stroke and Cerebrovascular Diseases, 30(1): 10544.

4. Sandin, KJ., Smith, BS. (1990) The measure of balance in sitting in stroke rehabilitation prognosis, Stroke, 21(1):82-6.

5. Lee, K., Lee, D., Hong, S., Shin., et al. (2021) The relationship between sitting balance, trunk control and mobility with predictive for current mobility level in survivors of sub-acute stroke, PLoS One, Aug 5;16(8):e0251977

6. Van de Port, IGL., Kwakkel, G., Schepers, V., Lindeman, E. (2006) Predicting mobility outcome one year after stroke: a progressive cohort study, Journal of Rehabilitation Medicine, 38(4):218-23.

7. Verheyden, G., Vereeck, L., Truijen S., et al (2006) Trunk performance after stroke and the relationship with balance, gait and functional ability. *Clin Rehabilitation.* 20:451–485.

8. National Clinical Guideline for Stroke for the UK and Ireland. (2023) London: Intercollegiate Stroke Working Party.

9. Mackie, P., Eng, J. (2023) The influence of seated exercises on balance, mobility and cardiometabolic health outcomes in individuals living with stroke: A systematic review and meta-analysis, Clinical Rehabilitation, 37(7): 927-41

10. Thijs, L., Voets, E., Dinissen, S., Merholz, J., Elsner, B., Lemmens, R., Verheyden, G. (2023) Trunk training following stroke, Cochrane Database of Systematic Reviews, CD013712.

11. Bernhardt, J., Hayward, K., Kwakkel, G., Ward, N. et al (2017) Consensus statements from the stroke recovery and rehabilitation roundtable. Agreed definitions and a shared vision for new standards in stroke recovery research: The stroke recovery and rehabilitation taskforce, Neurorehabilitation and Neural Repair, 31(9); 793-99.

12. Van Criekinge, TM., Heremans, C., Burridge, J.,Deutsch, JE., Hammerbeck, U., Hollands, K. et al.(2024) Standardised measurement of balance and mobility post stroke: Consensus based-core recommendations from the third stroke recovery and rehabilitation roundtable, International Journal of stroke, 19(2):158-168

13. Page, MJ., McKenzie, JE., Bossuyt, PM., Hoffman, TC., Mulrow, CD. Et al (2021) The PRISMA 2020 statement: an updated guidance for reporting systematic reviews, BMJ, 372:n71

14. Mourad Ouzzani, Hossam Hammady, Zbys Fedorowicz, and Ahmed Elmagarmid. Rayyan — a web and mobile app for systematic reviews. Systematic Reviews (2016) 5:210, DOI: 10.1186/s13643-016-0384-4.

15. Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, Cates CJ, Cheng H-Y, Corbett MS, Eldridge SM, Hernán MA, Hopewell S, Hróbjartsson A, Junqueira DR, Jüni P, Kirkham JJ, Lasserson T, Li T, McAleenan A, Reeves BC, Shepperd S, Shrier I, Stewart LA, Tilling K, White IR, Whiting PF, Higgins JPT. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ* 2019; 366: l4898.

16. Higgins, JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (editors). *Cochrane Handbook for Systematic Reviews of Interventions* version 6.3 (updated February 2022). Cochrane, 2022. Available from www.training.cochrane.org/handbook

17. Muckel, S and Merholz, J. (2014) Immediate effects of two attention strategies on trunk control on patients after stroke. A randomized controlled pilot trial, Clinical Rehabilitation, 28(7): 632–36

18. Pollock, A.,Durward, BR., Rowe, P., Paul, J. (2002) The effect of independent practice of motor tasks by stroke patients: a pilot randomized controlled trial, Clinical Rehabilitation, 16: 473–480

19. Saeys, W., Vereeck, L., Truijen, S., et al. (2012) Randomized controlled trial of truncal exercises early after stroke to improve balance and mobility. *Neurorehabilitation and Neural Repair*, 26:231–238.

20. Sheehy, L., Taillon-Hobson, A., Sveistrup, H., Bilodeau, M., Christine, Y., Hillel, F. (2020) Sitting Balance Exercise Performed Using Virtual Reality Training on a Stroke Rehabilitation Inpatient Service: A Randomized Controlled Study, Journal of Injury, Function and Rehabilitation, 12: 754-65.

21. Verheyden G, Vereeck L, Truijen S, et al. (2009) Additional exercises improve trunk performance after stroke: a pilot randomized controlled trial. *Neurorehabiliation and Neural repair.* 23:281–286.

22. Cabanas-Valdés R, Bagur-Calafat C, Girabent-Farrés M, Caballero-Gómez FM, Hernández-Valiño M, Urrútia Cuchí G. (2016) The effect of additional core stability exercises on improving dynamic sitting balance and trunk control for subacute stroke patients: a randomized controlled trial. Clinical Rehabilitation, 30(10): 1024-1033

23. Dean CM, Channon EF, Hall JM. (2007) Sitting training early after stroke improves sitting ability and quality and carries over to standing up but not to walking: a randomised controlled trial. Australian Journal of Physiotherapy. 53: 97–102.

24. Fujino, Y., Kazu, A., Kazuhiro, F., Shunichi, I., Shigeru, M., Hidetoshi, T. (2016) Does training sitting balance on a platform tilted 108 to the weak side improve trunk control in the acute phase after stroke? A randomized, controlled trial. Topics in Stroke Rehabilitation 23(1);43-9

25. Howe, TE., Taylor, I., Finn, P., Jones, H. (2005) Lateral weight transference exercises following acute stroke: a preliminary study of clinical effectiveness, Clinical Rehabilitation, 19:45-53

26. Khallaf, M. (2020) Effect of Task-Specific Training on Trunk Control and Balance in Patients with Subacute Stroke, Neurology Research International, ID 5090193

27. Lee, JH., Sang, BK., Lee, KW., Lee, SJ. Park, H, Kim, DW. (2017) The effect of a whole-body vibration therapy on the sitting balance of subacute stroke patients: a randomized controlled trial. Topics in Stroke Rehabilitation, 24(6): 457–462

28. Lee, M, Lee, K, Song, C. (2018) Game-Based Virtual Reality Canoe Paddling Training to Improve Postural Balance and Upper Extremity Function: A Preliminary Randomized Controlled Study of 30 Patients with Subacute Stroke, Medical Science Monitor, 24: 2590-2598

29. Lee, PY., Huang, J, Tseng, H, Yang, Y, Lin, S. (2020) Effects of Trunk Exercise on Unstable Surfaces in Persons with Stroke: A Randomized Controlled Trial. International Journal of Environmental Research for Public Health, 17, 9135

30. Kumar V, Babu K and Nayak A. (2011) Additional Trunk Training Improves sitting balance following Acute stroke: A pilot randomized controlled trial. International Journal of Current Research and Review, 2: 26–43

31. Karthikbabu S, Nayak A, Vijaykumar K,. (2011) Comparison of physio ball and plinth trunk exercises regimes on trunk control and functional balance in patients with acute stroke: a pilot randomized controlled trial. *Clinical Rehabilitation,* 25:709–719

32. Cabana-Valdes, R., Boix-Sala, L., Ferrer-Sola., M., Gracia, P., N., Torrello-Vivo, N., Morales-Zafra, M., Esteve-Hermandez, E., Guzman-Bernal, J., Caballero-Gomez, F., Molina-Hervas, B., Gonzalez-Hoelling, S., Lobato-Bonilla, A., Lopez-de-Cells, C., Canovas, E., and Urrutia, G. (2025) The effectiveness of core stability exercises on functional outcomes in early sub-acute stroke recovery: a randomized controlled trial, Topics in Stroke Rehabilitation, DOI: 10.1080/10749357.2024.2439712

33. Bank, J., Charles, K. and Morgan, P. (2016) What is the effect of additional physiotherapy on sitting balance following stroke compared to standard physiotherapy treatment: a systematic review, Topics in Stroke Rehabilitation, 23:15-25

Figure I. PRISMA 2020 flow diagram

Figure II. Risk of Bias

Figure III: Forest plot for primary outcome (sitting balance impairment)

Figure IV: Influence plot for balance outcome

Figure V: Forest plot for secondary outcome (sitting balance function)

Figure VI: Influence plot for sitting balance function

Table I: Summary of study characteristics

Appendix I: Search strategy

Appendix 1: Search strategy

1 "stroke".mp. or *Stroke/ or *Cerebral Infarction/
2 exp Brain Injuries/ or "acquired brain injur*".mp.
3 "brain h?emorrhage*".mp. or *Intracranial Hemorrhages/
4 1 or 2 or 3
5 exp Physical Therapy Modalities/ or "physiotherap*".mp.
6 ("sitting balance training" or "sitting balance measure*").mp.
7 ("seated rehabilitation" or "seated physiotherapy").mp.
8 "postural control".mp. or *Postural Balance/
9 4 and 5
10 6 or 7 or 8
11 9 and 10
12 *Outcome Assessment, Health Care/ or "outcome*".mp. or *Treatment Outcome/ or *Patient Outcome Assessment/
13 11 and 12
14 limit 13 to ("all adult (19 plus years)" and English)