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Rehabilitation for improving automobile driving after stroke (Review)

George S, Crotty M, Gelinas I, Devos H

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TABLE OF CONTENTS

[Intervention Review]

Rehabilitation for improving automobile driving after stroke

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ABSTRACT

Background

Interventions to improve driving ability after stroke, including driving simulation and retraining visual skills, have limited evaluation of their effectiveness to guide policy and practice.

Objectives

To determine whether any intervention, with the specific aim of maximising driving skills, improves the driving performance of people after stroke.

Search methods

We searched the Cochrane Stroke Group Trials register (August 2013), the Cochrane Central Register of Controlled Trials (*The Cochrane Library* 2012, Issue 3), MEDLINE (1950 to October 2013), EMBASE (1980 to October 2013), and six additional databases. To identify further published, unpublished and ongoing trials, we handsearched relevant journals and conference proceedings, searched trials and research registers, checked reference lists and contacted key researchers in the area.

Selection criteria

Randomised controlled trials (RCTs), quasi-randomised trials and cluster studies of rehabilitation interventions, with the specific aim of maximising driving skills or with an outcome of assessing driving skills in adults after stroke. The primary outcome of interest was the performance in an on-road assessment after training. Secondary outcomes included assessments of vision, cognition and driving behaviour.

Data collection and analysis

Two review authors independently selected trials based on pre-defined inclusion criteria, extracted the data and assessed risk of bias. A third review author moderated disagreements as required. The review authors contacted all investigators to obtain missing information.

Main results

We included four trials involving 245 participants in the review. Study sample sizes were generally small, and interventions, controls and outcome measures varied, and thus it was inappropriate to pool studies. Included studies were at a low risk of bias for the majority of domains, with a high/unclear risk of bias identified in the areas of: performance (participants not blinded to allocation), and attrition (incomplete outcome data due to withdrawal) bias. Intervention approaches included the contextual approach of driving simulation and underlying skill development approach, including the retraining of speed of visual processing and visual motor skills. The studies were conducted with people who were relatively young and the timing after stroke was varied. Primary outcome: there was no clear evidence of improved on-road scores immediately after training in any of the four studies, or at six months (mean difference 15 points on the Test Ride for Investigating Practical Fitness to Drive - Belgian version, 95% confidence intervals (CI) 4.56 to 34.56, P value = 0.15, one study, 83 participants). Secondary outcomes: road sign recognition was better in people who underwent training compared with control (mean difference 1.69 points on the Road Sign Recognition Task of the Stroke Driver Screening Assessment, 95% CI 0.51 to 2.87, P value = 0.007, one study, 73 participants). Significant findings were in favour of a simulator-based driving rehabilitation programme (based on one study with 73 participants) but these results should be interpreted with caution as they were based on a single study. Adverse effects were not reported. There was insufficient evidence to draw conclusions on the effects on vision, other measures of cognition, motor and functional activities, and driving behaviour with the intervention.

Authors' conclusions

There was insufficient evidence to reach conclusions about the use of rehabilitation to improve on-road driving skills after stroke. We found limited evidence that the use of a driving simulator may be beneficial in improving visuocognitive abilities, such as road sign recognition that are related to driving. Moreover, we were unable to find any RCTs that evaluated on-road driving lessons as an intervention. At present, it is unclear which impairments that influence driving ability after stroke are amenable to rehabilitation, and whether the contextual or remedial approaches, or a combination of both, are more efficacious.

PLAIN LANGUAGE SUMMARY

Driving rehabilitation for stroke

Background

After stroke, many people have limitations in their driving ability because of problems with movement, seeing and responding to hazards. Two approaches to treatment have been used. The first approach involves retraining the underlying skills of movement, thinking and sensing. The second approach involves using driving simulators and on-road driving practice in the form of lessons, which aim to improve the driver's skills.

Study characteristics

We identified four studies, up to October 2013, which involved 245 people after stroke. A wide range of interventions was used, including driving simulation, training on devices to improve speed of processing information, scanning and movement. All studies compared the effectiveness of the driving intervention on improving whether drivers passed or failed on a driving assessment.

Key results

There was no evidence that a driving intervention was more effective than no intervention. One trial found that training on a driving simulator resulted in improved performance on a test of recognising road signs immediately after training.

Quality of the evidence

Results should be interpreted with caution, as this was a single study. Further trials involving large numbers of participants, grouped according to their impairments and stroke type are required.

BACKGROUND

Description of the condition

Stroke is a major cause of disability around the world (CDCP 2000; Mathers 2001), which affects participation in daily activities and in social roles (Mayo 2002).

In recent decades, there has been an increase in survival rate and longevity after stroke, which has resulted in an increase in the number of people with perceptual and cognitive impairments who wish to resume driving (Korner-Bitensky 2006). People with stroke have a range of deficits that may influence their driving ability, including reduced visual fields (Gilhotra 2002), visual scanning, attention, information processing speed, physical abilities and visuospatial skills (Fisk 2002a; Fisk 2002b; Galski 1997; Lings 1991; Simms 1985; Sundet 1995; Szlyk 1993). These deficits translate into a reduction in on-road driving abilities, including difficulty with observation and delayed planning of vehicle manoeuvres (Lundqvist 2000).

The inability to drive can result in a number of adverse consequences in mood, life satisfaction and identity (Fonda 2001; Liddle 2009; Marottoli 1997; White 2012), and social isolation (Dickerson 2007; Lister 1999), and thus is an important contribution to quality of life after stroke (Griffen 2009). The post-stroke rate of return to driving varies according to length of time after stroke. These reportedly range from 19% (Allen 2007) to 30% (Aufman 2013), six months after admission to inpatient rehabilitation, to 50% up to five years post rehabilitation (Fisk 1997). Factors that positively influence the likelihood of returning to driving include being younger, having a lower level of disability (Aufman 2013; Fisk 1997), having fewer cognitive deficits (Fisk 2002b; Marshall 2007), and being provided with advice and assessment related to driving (Fisk 1997). Approximately 35% of stroke survivors will require driving-related rehabilitation before they can resume safe driving (Akinwuntan 2002).

Description of the intervention

Two approaches to rehabilitation for driving after stroke are used by clinicians (Mazer 2004): 1. retraining the underlying skill deficits through training of perceptual, cognitive, physical or visual skills, and 2. a contextual approach using driving simulators, on-road driving in the form of lessons, and cognitive tasks with a context-specific driving focus. The retraining of underlying skill deficits takes a number of forms including the use of paper and pencil tasks, off-the-shelf activities and cognitive games, and devices such as specialised computer programs and other apparatus designed for the retraining of a specific skill set. The approach of retraining underlying skill deficits assumes that retrained cognitive and perceptual skills will transfer to functional performance in on-road driving skills. Despite there being a weak relationship between cognitive deficits and actual driving performance (Bouillon 2006), this is a common approach in driving rehabilitation. The contextual approach takes the form of driving lessons, or driving simulators, which range from replica cars to driving-specific computerised programs, or cognitive skills with a context-specific driving focus such as route finding, give-way scenarios and matching signs with driving situations. The contextual approach of retraining aims to improve the driving skill set of the drivers.

Advantages and disadvantages exist practically in both approaches. In retraining underlying skill deficits, there is limited face validity in the methods of retraining. However, they are generally accessible and incur relatively small costs. In terms of contextual retraining, the techniques have more face validity, but the costs of lessons with driving instructors, limited access to driving instructors who have experience in retraining medical issues and access to equipment, such as simulators, can be restrictive.

After stroke, progress in abilities following rehabilitation is thought to occur due to a mixture of compensation, learning and physiological improvement (Kwakkel 2004). It is recognised that the experiences offered in stroke rehabilitation influences the learning that occurs in both the unaffected brain and the damaged brain through brain plasticity (Kleim 2008). Experience-dependent plasticity is described in the neuroscience literature as being based on a number of principles relevant to rehabilitation (Kleim 2008). Those principles of particular relevance to driving rehabilitation include: use it or lose it, use it and improve it, specificity, repetition and intensity matters, salience matters and transference. These principles are consistent with the evidence for task-specific training as an effective intervention in stroke rehabilitation (Hubbard 2009), which incorporates the concepts of learning-dependent plasticity through the recommended implementation strategies of: random assignment of tasks, reconstruction of the whole task, and reinforcement with timely and positive feedback (Hubbard 2009). These principles of experience-dependent plasticity and task-specific training can be manipulated to a greater or lesser degree based on the approach to retraining, for example, salience or meaning will be higher in driving lessons, whereas specificity, repetition and intensity can be controlled through the approaches of retraining skill deficits, such as speed of processing retraining. Random assignment of tasks and feedback can occur in both retraining underlying skill deficit and contextual approaches to retraining. It is not clear which principles, alone or a combination, result in a greater increase in rehabilitation outcomes, which in this case are skills for safe driving. In addition, driving itself is a complex and dynamic task, requiring 'top down' or conscious activity in novel situations, and 'bottom up' or unconscious activity in familiar situations (Akinwuntan 2012; George 2009).

Why it is important to do this review

Considering the importance of driving for community participation and quality of life, helping people with a stroke who have the potential to return to driving should be a priority. However, the choice of the training approach should be based on solid evidence. To our knowledge, there is no systematic review that has specifically examined the effectiveness of rehabilitation approaches to retrain driving skills after stroke. There is limited information to guide policy and practice on interventions related to driving for people with stroke (Mazer 2004). Other systematic reviews relevant to this review have been performed in relation to cognitive rehabilitation for attention deficits following stroke (Loetscher 2013), occupational therapy for people with problems in activities of daily living after stroke (Legg 2008), occupational therapy for cognitive impairment in people with a stroke (Hoffmann 2010), and virtual reality for stroke rehabilitation (Laver 2011). These reviews differ from our review in that the interventions themselves are not specifically aimed at improving driving skills. Instead they include the evaluation of the evidence for occupational therapy (Hoffmann 2010; Legg 2008), attention (Loetscher 2013), and virtual reality (Laver 2011) interventions for improvement in functional performance in basic activities of daily living (Hoffmann 2010; Laver 2011; Legg 2008); cognitive abilities (Hoffmann 2010; Loetscher 2013); and arm function (Laver 2011). These primary outcomes are measures of impairment or functional outcomes that relate to the ability to perform a range of daily tasks, not driving.

It is necessary to evaluate the effectiveness of different interventions for retraining of driving skills after stroke as an increasing number of people with perceptual and cognitive impairments after stroke wish to return to driving because of an increasing survival rate and longevity (Korner-Bitensky 2006). Furthermore, more people want to keep driving for longer, particularly women (Mitchell 2012), and our modern society involves greater mobility, Expensive devices are being promoted as providing recovery in impairments such as vision after stroke through plasticity and compensatory training. Thus, it is important to determine the most effective interventions in terms of retraining underlying skills deficits or driving-specific training, and to understand the mechanisms behind these interventions to maximise people's ability to drive after stroke.

OBJECTIVES

To determine whether any intervention, with the specific aim of maximising driving skills, improves the driving performance of people after stroke.

METHODS

Criteria for considering studies for this review

Types of studies

We planned to include randomised controlled trials (RCTs) and quasi-randomised (e.g. allocated by date of birth) trials (QRCTs) and cluster studies in the review. However, we did not find any relevant QRCTs or cluster studies and so only included RCTs. If we had found any relevant QRCTs, we intended to carry out a sensitivity analysis thereby limiting analysis to truly randomised studies. We would have considered cross-over trials as RCTs according to the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011). However, none were identified. We included studies that compared rehabilitation interventions with either no intervention or an alternative intervention.

Types of participants

All participants had a confirmed diagnosis of stroke, based on examination and scanning, as defined by the World Health Organization (WHO) (a syndrome of rapidly developing symptoms and signs of focal and at times global, loss of cerebral function lasting more than 24 hours) (WHO 1989), and were aged 16 years or over. We included participants with all types of strokes, levels of severity and at all stages post stroke. We excluded trials of participants with mixed populations if data could not be provided separately for participants with stroke in the published article, or could not be obtained from the authors of the trial.

Types of interventions

We considered all rehabilitation interventions that aimed to improve driving skills. These included driving simulators; training on devices aimed at improving skills related to driving such as attention or speed of processing; physical interventions to improve mobility, strength and co-ordination; class training to improve driving knowledge and driving-related cognitive tasks such as route finding.

Types of outcome measures

Primary outcomes

The primary outcome measure was performance in an on-road assessment. Examples of on-road assessment include a standardised assessment, which incorporates an in-traffic section that grades complexity from low to moderate traffic and progresses to areas with higher traffic (Akinwuntan 2003; Devos 2009). Performance was rated as dichotomous categorical (pass or fail) outcomes.

Secondary outcomes

We considered assessments of visual attention, reaction time, visual scanning, self efficacy, executive reasoning ability, and tests of visual perception, functional measures, physical measures of mobility, strength and co-ordination, and death as secondary outcome measures. Examples of secondary outcome assessments included: the Useful Field of View (UFOV) assessment (Visual Awareness Inc. 2002), Adelaide Driving Self-Efficacy Scale (George 2007), Trail Making Test Parts A and B (Reitan 1986), and component tests from the Stroke Drivers Screening Assessment (Lincoln 2004). We categorised the secondary outcomes into the domains of visual function, cognitive function, driving behaviours and other, for comparison.

Search methods for identification of studies

Electronic searches

See the 'Specialised register' section in the Cochrane Stroke Group module. We searched for trials in all languages and arranged translation of papers published in languages other than English.

We searched the Cochrane Stroke Group Trials Register, which was last searched by the Managing Editor in August 2013. In addition, we searched the following electronic bibliographic databases: the Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library* 2012, Issue 3) (Appendix 1), MEDLINE (Ovid 1950 to October 2013) (Appendix 2), EMBASE (Ovid 1980 to October 2013) (Appendix 3), CINAHL (EBSCO 1982 to October 2013) (Appendix 4), AMED (Ovid 1985 to October 2013) (Appendix 5), PsycINFO (Ovid 1940 to October 2013) (Appendix 6), PsycBITE (Psychological Database for Brain impairment Treatment Efficacy, www.psycbite.com/), OTseeker (www.otseeker.com/), and Dissertation Abstracts (Proquest, Search terms: (driving OR driver OR car OR vehicle) AND (rehabilitation OR assessment OR retraining) AND (stroke OR brain) (October 2013).

We developed the MEDLINE search strategy with the help of the Cochrane Stroke Group Trials Search Co-ordinator. We used relevant controlled vocabulary and free-text terms relating to the concepts stroke and automobile driving and added a trials filter to the strategy. An experienced medical librarian adapted the search strategy for the other databases.

Searching other resources

To identify further published, unpublished and ongoing trials, we:

1. searched the following ongoing trials registers: Current Controlled Trials (www.controlled-trials.com), National Institute of Health Clinical Trials Database (www.clinicaltrials.gov/), Stroke Trials Registry (www.strokecenter.org/trials/), WHO International Clinical Trials Registry Platform (www.who.int/ictrp/en/), and Australian New Zealand Clinical Trials Registry (www.anzctr.org.au/) to October 2013; driving AND rehabilitation OR retraining (other searches including stroke/brain injury/car/vehicle did not result in any other relevant studies);
2. used the Cited Reference Search within Science Citation Index (SCI) and Social Science Citation Index (SSCI) to track relevant references;
3. scanned the reference lists of all identified studies and reviews;
4. contacted key researchers and authors in the area, including governmental licensing authorities and engineering departments;
5. handsearched all occupational therapy, traffic and stroke journals, including supplements and conference abstracts that are not indexed in the databases listed above, and have not been searched on behalf of The Cochrane Collaboration to date. The journals that we handsearched were:
   i) *American Journal of Occupational Therapy* (1947 to 1949);
   ii) *Australian Occupational Therapy Journal* (1963 to 1990);
   iii) *Asian Journal of Occupational Therapy* (2001 to 2006);
   iv) *Canadian Journal of Occupational Therapy* (1955 to 1965);
   v) *Hong Kong Journal of Occupational Therapy* (2001 to latest issue);
   vi) *Indian Journal of Occupational Therapy* (2001 to 2005);
   vii) *New Zealand Journal of Occupational Therapy* (1957 to 1978, 1990 to 1995);
   viii) *Occupational Therapy in Health Care* (1984 to 1986);
   ix) *Occupational Therapy and Rehabilitation* (1938 to 1951);
   x) *South African Journal of Occupational Therapy* (1959 to 1991).

Data collection and analysis

Selection of studies

One review author (SG) performed the searches. Two review authors (SG and IG or HD) reviewed the titles and abstracts identified from the database searches to assess whether they met the pre-defined criteria (types of studies, participants, interventions and outcome measures). The first study selection resulted in the categories of included, excluded or unsure. The review authors obtained the full text of those studies in the categories of included and unsure, and two review authors (SG and IG or HD) independently completed the second study selection and corresponded with investigators to make a final decision on each trial's inclusion or exclusion. A third review author (MC) moderated any disagree-

ments. We documented the reasons for the exclusion of studies (see Characteristics of excluded studies table). Where studies published in non-English languages appeared relevant, we sought the full text and HD ascertained whether the study met the inclusion criteria.

Data extraction and management

Two review authors (SG or HD) independently recorded information using a pre-designed data extraction form for each selected study. We used the same criteria as those outlined in the *Cochrane Handbook for Systematic Reviews of Interventions* to evaluate each trial (Higgins 2011). Data extracted included: citation details of the study; the trial setting (e.g. hospital, community, outpatients); inclusion and exclusion criteria; participant details: descriptive characteristics including age, sex, location of stroke, type of stroke, time since onset of stroke, functional abilities of sample of basic activity of daily living performance, years of driving experience, sample size and number of drop-outs; methodological quality: according to The Cochrane Collaboration's tool for assessing risk (Appendix 7); interventions: description of the intervention, duration and dosage, comparison intervention; outcome measures: primary and secondary outcome measures and when they were administered (i.e. pre training, post training and follow-up); and adverse events. We resolved disagreements through discussion or by referral to a third review author (MC). The review authors contacted study authors for clarification when necessary to complete the review.

Assessment of risk of bias in included studies

Two review authors independently used The Cochrane Collaboration's tool for assessing risk of bias to assess the methodological quality of studies included in the review (Appendix 7). The tool included assessment of randomisation (sequence generation and allocation concealment), blinding, completeness of outcome data, selection of outcomes reported and other sources of bias including intention-to-treat analysis. We classified items as 'low risk', 'high risk' or 'unclear risk' of bias. We contacted the authors of included studies to request more information where insufficient information was published to assess the risk of bias. We resolved disagreements with help from a third review author (MC).

Measures of treatment effect

Two review authors independently classified outcome measures in terms of the area they assessed (e.g. on-road ability, visual function, cognitive function, driving behaviour and other). Two review authors were involved in independently classifying outcome measures. We planned to calculate risk ratios (RR) with 95% confidence intervals (CIs) for any dichotomous outcomes, if recorded. We calculated mean differences (MD) for continuous variables as appropriate.

Unit of analysis issues

The unit of randomisation in these trials was the individual participant. We did not include any cluster RCTs.

Dealing with missing data

We performed intention-to-treat analysis if possible to include all participants randomised. Where drop-outs had been clearly identified for an outcome assessment, we used the actual denominator of the participants contributing data. We contacted study authors to obtain any missing data.

Assessment of heterogeneity

We have described the variability in participants, interventions, comparison and outcomes studied in the Characteristics of included studies and Table 1. Because there are only four studies, we did not conduct any subgroup analyses (Higgins 2011).

Assessment of reporting biases

We reduced the impact of publication bias by searching clinical registers for studies. We investigated selective outcome reporting through the comparison of the methods sections of papers with the results reported.

Data synthesis

We intended to synthesise the data for continuous data by calculating two types of estimates for measure of treatment difference. We planned to use the MD when the same test was used in the pooled trials, and the standardised mean difference (SMD) when different tests were used. In both cases, we planned to calculate the corresponding 95% CI. We planned to calculate RR with 95% CI for dichotomous outcomes.

Subgroup analysis and investigation of heterogeneity

We planned to perform subgroup analyses to determine whether outcomes varied according to the type and severity of stroke, time since onset of stroke and dosage of intervention. However, due to the variability of the studies it was inappropriate to pool the results and explore heterogeneity. If we had been able to pool all results, we would have presented an overall estimate of the treatment effect using a fixed-effect model and assessed heterogeneity by the visual inspection of the forest plot (analysis) combined with the I^2 statistic (Higgins 2011).

Sensitivity analysis

We intended to perform sensitivity analyses to examine the impact of risk of bias in included studies using the 'Risk of bias' assessment tool (Appendix 7). If studies were able to be pooled together, we planned to conduct a post-hoc sensitivity analysis to

determine differences between using a fixed-effect and a random-effects model to test the robustness of the results.

RESULTS

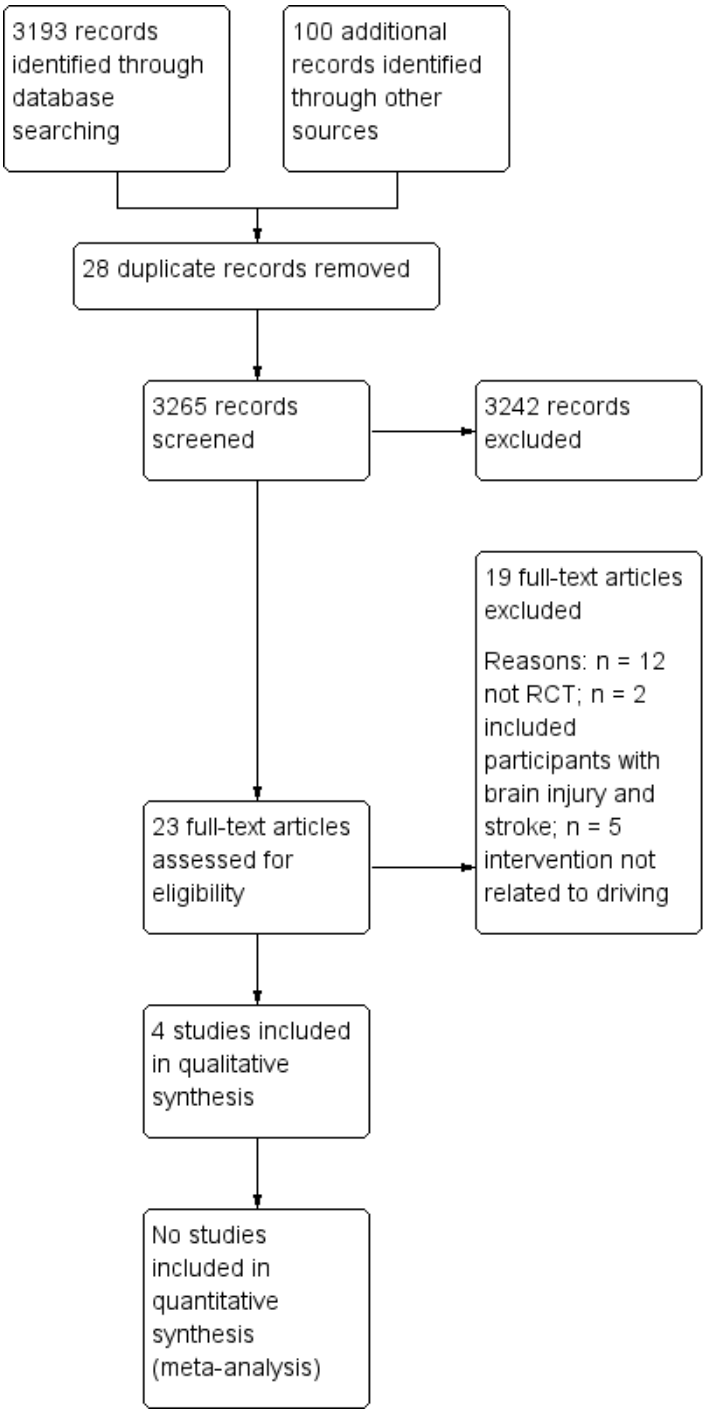
Description of studies

See: Characteristics of included studies; Characteristics of excluded studies.

Results of the search

See Figure 1. We identified 140 studies from searching the Cochrane Stroke Group trials register and 3053 references from the database searches totalling 3193 references to studies. A search of the trials registries elicited a further 100 potentially relevant studies. From the 3293 titles and abstracts retrieved, we sought 23 of the articles in full text for further review, including three published papers in languages other than English. We did not find any ongoing studies. We grouped articles reporting the same study. We removed articles that did not meet the inclusion criteria, such as studies that used interventions not aimed at improving driving ability and non-RCTs. We included four studies in the review (Akinwuntan 2005; Crotty 2009; Mazer 2003; Mazer 2005). We have provided details on 11 studies (Hitosugi 2011; Inoue 2006; Jacobs 2012; Katz 1990; Klavora 1995; Kotterba 2005; Lings 1991; Mazer 2001; Monning 2002; Schultheis 2007; Söderström 2006) (Characteristics of excluded studies) that were close to, but did not meet, the inclusion criteria.

Figure 1. Study flow diagram.



Included studies

We identified four RCTs involving 245 participants (Akinwuntan 2005; Crotty 2009; Mazer 2003; Mazer 2005) (see Characteristics of included studies). All included studies investigated the effect of interventions on improving the driving performance of people after stroke.

Sample characteristics

The included studies were performed in three different countries: two in Canada, one in Australia and one in Belgium. All trials were published in English and took place between 2002 and 2005. Two studies involved sample sizes between 26 and 50 participants (Crotty 2009; Mazer 2005), and two studies involved samples of 83 (Akinwuntan 2005) and 97 (Mazer 2003). Therefore, 245 participants post stroke were included in the trials. All studies included more men than women. Participants were relatively young with studies reporting mean ages of 54 to 69 years. For those studies in which information regarding side of lesion was available, two had fairly equal numbers of participants with left and right lesions (Akinwuntan 2005; Mazer 2003), whereas one study had twice as many participants with right-sided lesions than left (Crotty 2009), most likely due to exclusion criteria of needing a left foot accelerator for on-road assessment.

Inclusion criteria were specified in all studies: one trial recruited participants after one-month post stroke (Crotty 2009), one within three months of stroke (Akinwuntan 2005), and one within six months (Mazer 2003). One study recruited participants for up to more than 12 months post stroke (Mazer 2005) and one after two years (Crotty 2009). The mean recruitment time since stroke for each study is reported in the Characteristics of included studies table.

One study specified hemispheric stroke in the inclusion criteria (Mazer 2003), and another having failed a driving evaluation (Mazer 2005).

All studies listed the presence of aphasia or an inability to communicate as an exclusion criteria. Furthermore, all studies listed medical or visual guidelines from the relevant national guidelines including homonymous hemianopia (Crotty 2009), and epilepsy as exclusion criteria. Other exclusion criteria specified included: aged 75 years old or older (Akinwuntan 2005); greater physical disability as indicated by requiring the use of greater modifications than a spinner knob on the steering wheel, such as a left foot accelerator to complete on-road assessment (Crotty 2009); and significant cognitive impairment < 6 on the Pfeiffer Short Portable Mental Status Questionnaire (Mazer 2003).

Two studies provided clear details of participant recruitment (Akinwuntan 2005; Crotty 2009), with the data from the studies showing that 67.9% (standard deviation (SD) 2.9%) of the target population screened were recruited. Table 2 shows further details of recruitment and retention.

Interventions

Intervention approaches

Two studies focused on contextual training in the form of driving simulators (Akinwuntan 2005; Mazer 2005), and two on underlying skill development, one using training on a Dynavision device (Crotty 2009), and the other Useful Field of View training (Mazer 2003). The simulator used in one study was a Ford-fiesta vehicle 1.8 car with automatic transmission with all mechanical parts, powered on a STISIM Drive System with an online interactive driving scenario that took 25 minutes to complete, which is projected onto a screen (2.3 metres by 1.7 metres) with a visual angle of 45 degrees (Akinwuntan 2005). The second study used the Faros F-230 PMR driving simulator, which provides a variety of interactive driving scenarios of different lengths projected in three-dimensional images on three colour monitors (Mazer 2005). Participants were seated into a vehicle that included an adjustable seat, steering wheel, accelerator pedal, gearshift, handbrake, seat belt and dashboard manufactured by Renault. The simulator was equipped with a variety of driver aids and could simulate automatic or standard transmission. An automatic transmission was used for the study.

The Dynavision device (Klavora 1996), used in one study (Crotty 2009), is a tool that aims to retrain skills relevant to driving as it involves continuous execution of a wide scan, moving from central to peripheral visual fields; the combination of motor and visual processing; and the speed of actions or response speed. The Dynavision measures approximately 120cm^2, consists of 64 small square buttons, illuminated by a small light bulb and arranged in patterns of five rings. Participants were required to locate an illuminated button and hit it with their hand as quickly as possible. Exercises performed were self paced or apparatus-paced.

The UFOV training (Visual Awareness Inc. 2002) used in one trial (Mazer 2003) involved a large screen computer that used specialised software to retrain three aspects of visual attention: visual processing speed, divided attention and selective attention. The first task, processing speed, required the participant to identify a centrally located object, either a car or a truck. The participant must indicate that they saw a car or a truck by touching the appropriate image on the computer screen after each trial. The duration of object presentation was gradually decreased until the participant could no longer identify which of the two objects was presented. The duration of presentation ranged from 250 milliseconds (ms)

to 12.5 ms. The second task, divided attention, required the participant to identify the centrally located target and to locate a simultaneously presented peripheral target. The peripheral target appeared randomly at any of 24 locations, representing all combinations of eccentricity and directions. Divided attention was tested at varying exposure durations, ranging from 240 ms to 40 ms. Time response was the duration at which participants achieved 75% accuracy. The third task was the evaluation of selective attention. This test provided a measure of distractibility by having participants perform the same tasks as the second task but with the addition of distracters in the field. The participant was presented with white triangles throughout the screen to evaluate their ability to differentiate the peripheral target from the distracters.

Setting

The intervention was delivered in an outpatient setting in all studies except one, which occurred while participants were admitted to the rehabilitation hospital (Akinwuntan 2005).

Amount of intervention provided

The total dose of therapy ranged from 12 (Crotty 2009) to 17 hours (Mazer 2003) with a mean across studies of 15 hours (SD 2.16). The intervention occurred across a range of five weeks (Akinwuntan 2005) to 10 weeks (Mazer 2003), with a mean of 7.25 weeks (SD 2.22). One study stated that the mean time of each session for the intervention group was 34 minutes (SD 6.7) and control group 43.8 minutes (SD 8.0) (Mazer 2003). Other trials reported a general time of 40 minutes (Crotty 2009) and 60 minutes (Akinwuntan 2005; Mazer 2005) per intervention session.

Comparison interventions

Two of the trials compared the driving intervention with no intervention (Crotty 2009; Mazer 2005). One trial compared intervention with commercially available software programs (Mazer 2003) to train perceptual and cognitive skills with one also using driving-related cognitive tasks and off-the-shelf paper and pencil or puzzle tasks (Akinwuntan 2005).

Outcomes

A wide range of outcomes was used. All studies measured outcomes close to post intervention. One study included follow-up at six months and five years after stroke onset (Akinwuntan 2005). Outcome measures for each pre-defined categories are detailed in Table 1, as on-road assessment, visual tests, cognitive tests and driving-related and other. No studies reported on adverse events.

Excluded studies

We excluded 11 studies: 10 were non-RCTs (Hitosugi 2011; Inoue 2006; Katz 1990; Klavora 1995; Kotterba 2005; Lings 1991; Mazer 2001; Monning 2002; Schultheis 2007; Söderström 2006), and in one combined data for brain injury and stroke (Jacobs 2012) (Characteristics of excluded studies).

Risk of bias in included studies

See Figure 2 and Figure 3.

Figure 2. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

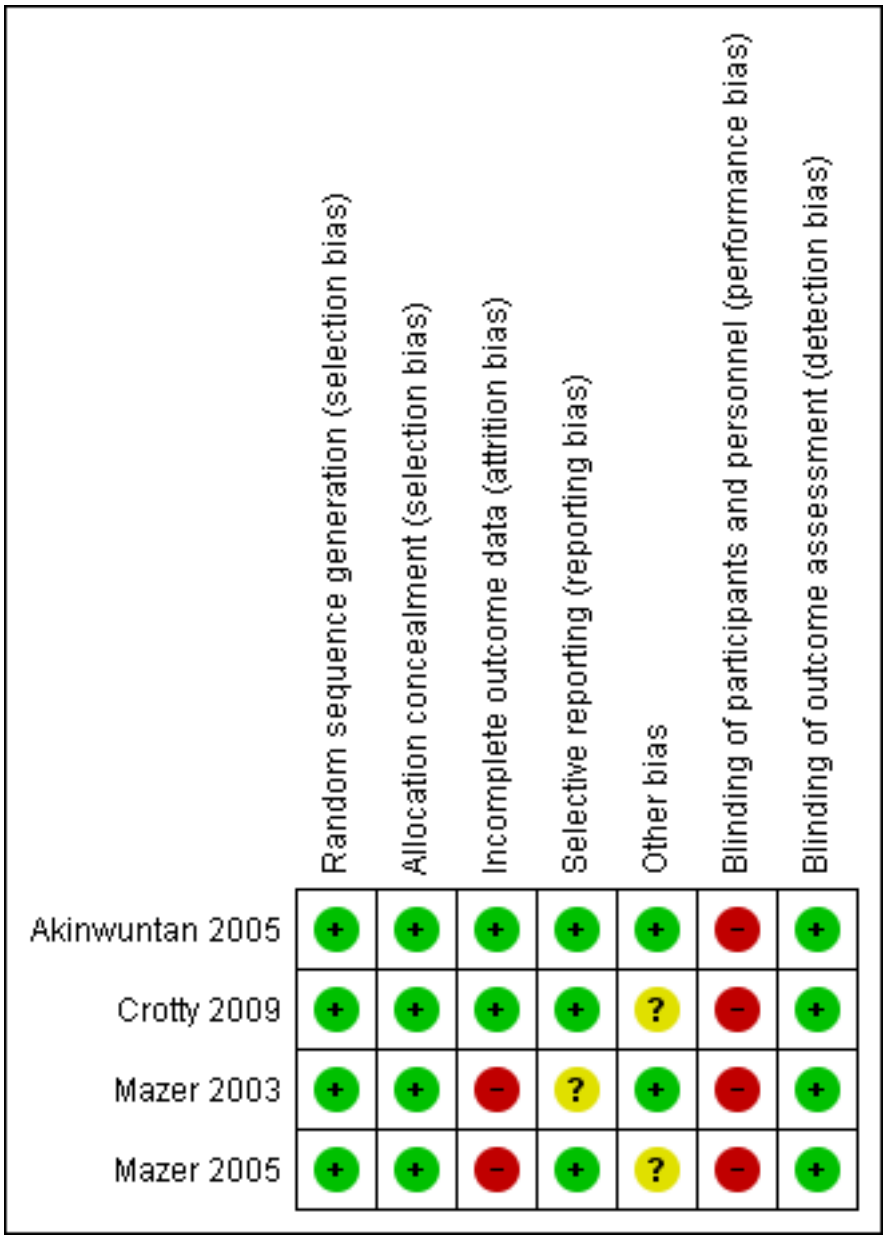
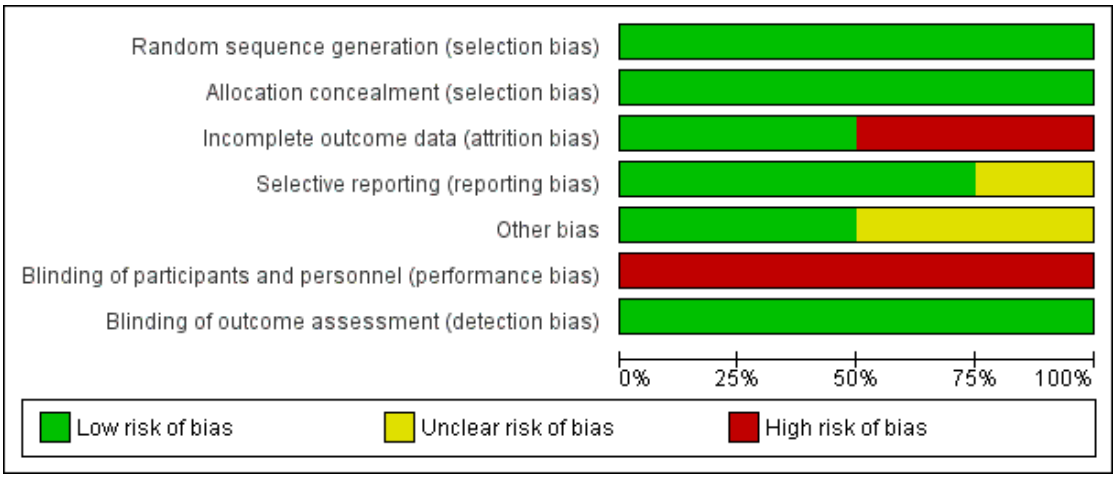


Figure 3. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.



Allocation

Allocation concealment was adequate in all trials (Akinwuntan 2005; Crotty 2009; Mazer 2003; Mazer 2005).

Blinding

All trials included blinding of the outcome assessors (Akinwuntan 2005; Crotty 2009; Mazer 2003; Mazer 2005). None of the trials were able to blind participants or personnel.

Incomplete outcome data

Two trials reported that they performed intention-to-treat analyses (Akinwuntan 2005; Crotty 2009). It was unclear whether intention-to-treat-analyses were performed in two trials (Mazer 2003; Mazer 2005), in which analyses were completed on the number of participants who contributed data and completed interventions.

Selective reporting

All four trials reported all outcomes and negative results (Akinwuntan 2005; Crotty 2009; Mazer 2003; Mazer 2005).

Other potential sources of bias

Other potential sources of bias identified were participant bias, as people with more disability or more likely to have poor driving habits may not have entered the study as results of on-road assessment were sent to the licensing agencies (Crotty 2009; Mazer 2005), which was a legal requirement.

Effects of interventions

Primary outcome

All four trials presented outcomes for the primary outcome of results for an on-road assessment. There was significant clinical heterogeneity between studies in regards to the types of interventions, outcomes and comparison intervention. Thus, it was inappropriate to pool data.

Comparison 1.1: on-road assessment result

Two studies compared driving simulator interventions, in one trial with driving-related tasks (Akinwuntan 2005) and one trial with no intervention (Mazer 2005).

In the first trial (Akinwuntan 2005), both groups improved in the on-road assessment from pre-post training with the intervention group showing more improvement than the control, but the difference between groups did not reach significance. In addition, both groups improved on the three-class decision pre-post training ("unfit to drive", "temporarily unfit to drive", "fit to drive"), with the difference trending towards significance. Furthermore,

changes in decision pre-post training was significantly different between the groups with the experimental groups demonstrating greater changes in decision. At the six-month follow-up, the intervention group maintained the on-road result whereas the control group deteriorated. In addition, the intervention group did not significantly improve on the on-road total score compared with the control group (MD 15, 95% CI -4.56 to 34.56, P value = 0.13) (Analysis 1.1). However, a significant difference between the intervention and control group and on-road score, in favour of the intervention group, was found on post hoc Generalised Estimating Equation analysis at six months (β = 0.502, 95% CI 0.148 to 0.856, P value = 0.005). In terms of individual driving skills, the intervention group demonstrated more improvement than the control group in: anticipation and perception of signs, visual behaviour and communication, quality of traffic participation, and turning left at follow-up only; and for the item of quality of traffic participation immediately after training. These benefits had disappeared at the five-year follow-up. Interestingly, the simulator-based training was found to be more effective for well-educated and less disabled people with stroke (measured by the Barthel Index) at the six-month follow-up (Akinwuntan 2005). Simulator training did not improve driving skills of operational manoeuvres including road positioning, steering and pedalling (Akinwuntan 2005).

In the second trial, where an on-road assessment was performed post training only, using driving simulation as the intervention, there was no significant difference between groups in the proportion of individuals who passed the driving evaluation (Mazer 2005). Participants with moderate impairments who received simulator training were more likely to pass the driving test compared with participants in the control groups.

The remaining two trials also performed an on-road assessment post training only. One trial compared the Dynavision device with no intervention and found no significant difference in on-road results in terms of pass or fail (Crotty 2009). A higher proportion of participants in the intervention group compared with the control group passed the on-road assessment. However, this did not reach significance.

Similarly, the other trial, which compared UFOV training with traditional computerised visuoperception training, found no significant difference in on-road results in terms of pass or fail post training (Mazer 2003). There was a two-fold increase in the rate of success in the on-road tests for people with right-sided lesions in the intervention group.

Secondary outcomes

Comparison 1.2: visual function

One study reported outcomes of binocular, monocular and kinetic vision (Akinwuntan 2005). There were no significant differences between control and intervention groups from pre to post training in visual function scores.

Two trials reported outcomes of visual scanning (Crotty 2009; Mazer 2003). There were no significant differences between control and intervention groups on change in visual scanning scores.

Comparison 1.3: cognitive function

Three trials reported using the UFOV test as secondary outcomes (Akinwuntan 2005; Mazer 2003; Mazer 2005). In the two studies that did not use the UFOV training, there were no significant differences between control and intervention groups from pre to post training in UFOV scores (Akinwuntan 2005; Mazer 2005). There was a significant difference with both groups improving on the scores from pre to post training in one trial that used a simulator for the intervention (Akinwuntan 2005). Furthermore, in the one trial that used UFOV training as the intervention (Mazer 2003), the intervention group obtained significantly better scores from pre to post training.

In the one trial that used components of the Stroke Driver Screening Assessment (dot cancellation, square matrix and road sign recognition test) as secondary outcomes, there was no significant differences from pre to post training except in the road sign recognition test, in which the intervention group demonstrated a significant improvement compared with the control group (MD 1.69 points, 95% CI 0.51 to 2.87: P value = 0.005) (Akinwuntan 2005) (Analysis 1.2).

In the two studies that used reaction time as a secondary outcome - one the complex reaction timer (Mazer 2003), and the other response speed (Crotty 2009) - there were no significant differences between the control and intervention groups on change in reaction time scores.

In all other cognitive function secondary outcomes, there were no significant differences between the control and intervention groups (Mazer 2003; Mazer 2005).

Comparison 1.4: driving behaviours

In one trial that used self efficacy of driving behaviours as a secondary outcome measure, there was no significant difference from pre to post training between the control and intervention groups (Crotty 2009). In another trial that evaluated driving status, kilometres driven, and self reported traffic tickets and accidents, the five-year data were combined for groups and not between intervention and control groups so no comparison could be made (Akinwuntan 2005).

Comparison 1.5: other secondary outcomes

Other secondary outcomes included an official pre-driving assessment with a licensing agency and the Hospital Anxiety and Depression Scale in one trial (Akinwuntan 2005). No significant differences at five years occurred between the intervention and con-

trol groups on these other secondary outcomes. Scoring on the Hospital Anxiety and Depression Scale was combined for the control and intervention groups so could not be compared.

Two trials used functional assessments as secondary outcome measures, namely the Barthel Index (Akinwuntan 2005), and the Functional Independent Measure (FIM) (Mazer 2005). No significant differences were found from pre training and five-year follow-up on the Barthel Index (Akinwuntan 2005), and pre to post training on the FIM (Mazer 2005).

DISCUSSION

Summary of main results

We found four studies (245 participants) eligible for inclusion in the review. Due to clinical heterogeneity between studies it was inappropriate to pool data.

On-road assessment results

All four trials assessed the results of an on-road assessment following intervention. Two studies focused on contextual training in the form of driving simulators (Akinwuntan 2005; Mazer 2005), with one comparing driving simulation with no intervention (Mazer 2005), and the other with commercially available puzzle and paper and pencil games (Akinwuntan 2005), to train perceptual and cognitive skills and driving-related cognitive tasks. Two of the trials focused on training underlying skill development, one using training on a Dynavision device (Crotty 2009), and the other UFOV training (Mazer 2003), with the first comparing with no intervention (Crotty 2009), and the second with training on commercially available software programs (Mazer 2003). All studies found no significant differences in pass or fail rates on outcome between groups post intervention (Akinwuntan 2005; Crotty 2009; Mazer 2003; Mazer 2005).

One study found significant improvement in driving behaviours in the on-road assessment between the intervention and control groups at six months on turning left in a European context, visual behaviour and communication, anticipation/perception of signs, and quality of traffic participation. Simulator training did not appear to retrain operational manoeuvres such as positioning on road, steering and pedalling (Akinwuntan 2005).

Secondary outcomes

In one trial, a road sign recognition test showed significance between the intervention and control groups from pre and post training (Akinwuntan 2005) (Analysis 1.2). We were unable to conduct analyses due to heterogeneity between studies. There was limited information and insufficient evidence from which to draw conclusions regarding the effect of intervention with the aim of improving driving performance for people after stroke related to the secondary outcomes of driving behaviours, cognitive functions, visual functions, functional abilities and depression.

Interestingly, there was a significant difference at baseline between the intervention and control groups in visual function scores of neglect and scan sub-tests (Crotty 2009), and cognitive functions scores of reaction time scores in sub-test of two choice inspection, response, and reaction times (Crotty 2009).

Overall completeness and applicability of evidence

Despite our extensive search strategy, we found few studies eligible for inclusion in the review. In addition, there was significant heterogeneity between the included studies with regards to the interventions used, comparison interventions and outcomes assessed. The majority of the studies involved small sample sizes and a heterogeneous sample of people with stroke with different lesions, different impairments and varying times since the onset of their stroke. All of the studies were published since 2003 demonstrating this is a relatively new approach in rehabilitation.

Two of the studies involved driving simulation (Akinwuntan 2005; Mazer 2005), one the Dynavision device (Crotty 2009), and the other the UFOV training (Mazer 2003), which are devices and equipment not readily available in clinical rehabilitation settings. Only one study was identified that evaluated driving lessons (Monning 2002), which was not included in the review as it was not an RCT. More research is required to investigate whether driving interventions after stroke aimed at retraining underlying cognitive skills, and contextual training in the form of driving lessons, the most commonly used intervention offered in clinical settings, lead to improved driving skills after stroke.

Quality of the evidence

Many studies involved small sample sizes with heterogeneous populations of stroke. Larger studies with more homogeneous stroke groups in terms of lesion, impairments and time since stroke are required to provide more conclusive evidence.

Potential biases in the review process

Our search strategy was comprehensive, including a search of clinical registers and the grey literature. However, it is possible that studies were missed. We contacted the authors of included studies and all the authors responded, therefore, the methodological assessment of each study is as accurate as possible.

Agreements and disagreements with other studies or reviews

No other systematic reviews have been performed in evaluating the evidence of the effectiveness of rehabilitation interventions targeted at driving in people with stroke.

AUTHORS' CONCLUSIONS

Implications for practice

The findings of this review suggest that there is insufficient evidence to reach conclusions about the effectiveness of rehabilitation of on-road driving skills after stroke. We found limited evidence that the use of a driving simulator may be beneficial in improving cognitive abilities such as road sign recognition that are related to driving. Moreover, we were unable to find any randomised controlled trials (RCTs) that had evaluated on-road driving lessons as an intervention, the most commonly used clinical intervention for retraining driving skills. In addition, as driving interventions may vary from inexpensive pen-and-paper tasks to expensive equipment such as driving simulators, it is unclear what aspects of the intervention are the most valuable for individuals with differing impairments. The findings of the review suggest that clinicians who currently have access to driver retraining devices could continue their use as part of a rehabilitation programme after stroke if it corresponds with individual patients' goals, preferences and abilities. However, they need to be aware that this practice is not yet based on evidence in all cases except for the use of a specific driving simulator (Akinwuntan 2005), for which limited evidence of effectiveness is available.

In addition, the applicability of the intervention to stroke survivors needs further research to explore what type of person in terms of level of disability and impairment is most likely to benefit, the stage of rehabilitation at which the intervention is offered that would provide the best benefits (e.g. acute, post-acute or chronic), and how acceptable each approach is to people when compared with contextual training in the form of lessons. It is unclear at present which impairments that influence driving ability after stroke are amenable to rehabilitation, and whether the contextual or remedial approaches, or a combination of both, are more efficacious.

Implications for research

More RCTs are required to determine which types of driving interventions are the most effective after stroke. Researchers should ensure that future RCTs are adequately powered. A driving intervention should be compared with a control of no intervention to ensure that results are due to the specific therapy and not the dose of therapy. Studies are required with different participants, as homogenous in characteristics as possible including impairments, lesions, severity and time since stroke, to determine the client group that will most benefit from the intervention. Thus, future trials should have larger samples to enable stratification of randomisation as per characteristics and include standardised screening of visual attention, visual neglect and motor severity to enable this to occur. In addition, future trials should include smaller studies that target specific characteristics, for example, right-sided strokes only, with a targeted intervention, for example, UFOV training as damage to the right hemisphere often leads to changes in visual processing.

In terms of outcome measures, examination of the practice effects needs to happen, as this is not known. Ideally, studies need to include an on-road assessment pre and post training, as occurred in one trial (Akinwuntan 2005). The on-road assessment needs to be reliable and valid, with specific driving behaviours within the drive being differentiated. This will enable comparison in driving performance pre and post training to determine specifically the effect the intervention is having on driving behaviour.

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* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Akinwuntan 2005

Methods	RCT
Participants	Rehabilitation unit of the University Hospital Pellenberg, Belgium 83 participants: 42 intervention, 41 control Inclusion criteria: within 3 months of first stroke, in possession of a valid driver's licence, actively driving before stroke Exclusion criteria: ≥ 75 years old, history of epilepsy within previous 6 months, severe motor or sensory aphasia Mean age (years): intervention 54 (SD 12), control 54 (SD 11) 81% male Side of lesion: 44% left, 52% right, 4% bilateral Stroke details: 77% ischaemic, 44% right hemiparesis Mean time post stroke (days): intervention 53 (SD 6), control 54 (SD 6)
Interventions	Experimental intervention: driving simulator-based training in full-sized automatic gear transmission Ford Fiesta. Adaptive equipment such as spinner knob on steering wheel and left-foot accelerator were added as necessary. Training was graded for familiarisation, then advanced to an assortment of 5-km driving scenarios including regular traffic demands such as lane tracking, speed control, road sign recognition, anticipation hazard perception and overtaking. Each skill was initially trained on a scenario that simulated daily driving tasks and then later the same scenarios were presented with distracters to train divided attention Control intervention: driving-related cognitive tasks. These included route finding on a paper or road map, recognition of road and traffic signs using cards, memory training with numbers and forming different patterns using tiles, utilising commercially available games including 'Rush Hour' and 'Tantrix' Sessions were 60 minutes, 3 times a week for 5 weeks (15 hours total)
Outcomes	Outcomes recorded at baseline, post intervention and at 6 months with some participants followed up at 5 years Pre and post training • Primary outcome: on-road driving test (using Test Ride for Investigating Practical Fitness to Drive checklist), decision of fitness to drive ("fit to drive", "temporarily unfit to drive", "unfit to drive") • Secondary outcomes: ○ vision tests: monocular and binocular acuity, kinetic vision ○ cognitive tests: UFOV Test, components of the Stroke Driver Screening Assessment (dot cancellation, square matrix and road sign recognition test) 6-months follow-up • Primary outcome: outcome of official pre-driving assessment with the Belgian Road Safety Institute, decision of fitness to drive, and pass/fail classifications (pass - "fit to drive", fail - "temporarily unfit to drive", "unfit to drive") • Secondary outcomes: vision and cognitive tests mentioned above Baseline and 5-year follow-up

Akinwuntan 2005 (*Continued*)

	• Primary outcome: as for 6-month follow-up and driving status (actively driving or stopped driving) • Secondary outcomes: as for 6-month follow-up, Barthel Index, Hospital Anxiety and Depression Scale, number of kilometres driven per year, number of self reported traffic tickets and accidents
Notes	Combined data from Akinwuntan 2005; Akinwuntan 2010; Devos 2009; Devos 2010

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Computerised number generation
Allocation concealment (selection bias)	Low risk	Allocation managed by an independent person
Incomplete outcome data (attrition bias) All outcomes	Low risk	There was a large amount of missing data due to the number of participants who withdrew (12% withdrew from the intervention group and 10% from the control group, 25% of participants were lost to follow-up, and 26.5% at the 5-year follow-up) Intention-to-treat analysis determined that drop-out was random and balanced evenly across groups
Selective reporting (reporting bias)	Low risk	All outcomes reported, including negative results
Other bias	Low risk	No other outcomes were collected
Blinding of participants and personnel (performance bias) All outcomes	High risk	Participants not blinded to allocation
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Outcome assessors blinded to allocation

Crotty 2009

Methods	RCT
Participants	4 rehabilitation centres in Adelaide, Australia 26 participants: 13 intervention, 13 control Inclusion criteria: no visual field impairments, binocular vision of minimum 6/12, minimum 1 month post stroke, desire to return to driving, clearance from medical practitioner to perform driving assessment, holder of driver's licence and driving pre stroke Exclusion criteria: visual field < 120 degrees; unable to provide informed consent; required the use of greater modifications than a spinner knob on the steering wheel, such as a left foot accelerator to complete on-road assessment

Crotty 2009 (*Continued*)

	Mean age (years): 65.6 (SD 13.1) 92.31% male Side of lesion: 27% left, 58% right, 15% other Median time post stroke (days): 83.5 (range 29 to 816)
Interventions	Experimental intervention: training on the Dynavision device (developed to train visuo-motor abilities) using a standardised programme of intervention of grading in complexity of tasks from self paced to apparatus paced, in which the time required to respond was reduced as skilled level increased Control intervention: no intervention and wait-listed for 6 weeks Sessions were 3 times a week for 6 weeks, each session approximately 40 minutes (total of 12 hours)
Outcomes	Outcomes recorded at baseline and post intervention • Primary outcome: on-road driving test (pass that included lessons, or fail) • Secondary outcomes ○ vision tests: visual scanning ○ cognitive tests: response speed and driving self efficacy
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Computerised number generation
Allocation concealment (selection bias)	Low risk	Allocation managed by an independent person
Incomplete outcome data (attrition bias) All outcomes	Low risk	There were some missing data due to the number of participants who withdrew (12% withdrew from their allocated intervention, 16% of participants were lost to follow-up) Intention-to-treat analysis performed
Selective reporting (reporting bias)	Low risk	All outcomes and negative results reported
Other bias	Unclear risk	Participation bias as participants may have been reluctant to enter study, particularly those with more disability and poor driving skills as results were sent to licensing agency
Blinding of participants and personnel (performance bias) All outcomes	High risk	Participants not blinded to allocation
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Outcome assessors blinded to allocation

Mazer 2003

Methods	RCT
Participants	Acute care and rehabilitation centres in Montreal area, Quebec, Canada 97 participants: 47 intervention, 50 control Inclusion criteria: hemispheric stroke occurring within previous 6 months, licensed to drive prior to stroke, having driven in 6 months prior to stroke, a desire to return to driving, willing to participate in either 20-session training programme, were available during daylight hours, and signed an informed consent form Exclusion criteria: those criteria indicated by the Canadian Medical Association, visual homonymous hemianopia, primary visual impairment inadequately improved with corrective lenses, class IV cardiac status, seizure activity within the previous year, bilateral lesion, cerebellar or brainstem stroke, severe cognitive deficit (< 6 on Pfeiffer Short Portable Mental Status Questionnaire), severe perceptual, comprehension or motor deficit, as determined by treating medical team, or an inability to communicate in English or French Mean age (years): 66.5 years (SD intervention 11.4, control 8.9) 73% male Side of lesion: 48.5% left, 51.5% right Mean time post stroke (days): intervention 91.2 (SD 51.8), control 66.7 (SD 28.2)
Interventions	Experimental Intervention: 20-session training programme with the UFOV tool including speed of processing, divided and selective attention tasks, which followed a standard training protocol designed according to participant's pre-test evaluation. The programme was graded by increasing speed of presentation of stimuli, eccentricity, colours of peripheral targets from distinct colours to white, which is difficult to see Control Intervention: 20-session training programme using same touch screen as intervention group using commercially available software programs commonly used by occupational therapists to retrain perceptual and cognitive skills in neurologically impaired adults including Tetris, Mastermind, Othello and Jigsaw Puzzle chosen as did not include aspects of speed of visual processing. The therapist graded the level of complexity in each programme as participants' performance improved In addition, all participants, regardless of allocation, received 4 sessions of physical retraining on a simulator, which provided training on steering, acceleration, braking and use of adaptive equipment Both groups received 2 to 4 treatment sessions per week, with duration ranging from 30 to 60 minutes depending on individuals' needs and abilities The mean number of treatment sessions did not differ significantly between groups, with intervention mean 17.5 (SD 5.3), control mean 18.1 (SD 5.0), P value = 0.53. The duration of sessions differed significantly between groups, with intervention mean 34.1 minutes (SD 6.7) and control mean 43.8 minutes (SD 8.0), P value < 0.0001
Outcomes	Outcomes recorded at baseline and post intervention Primary outcome: on-road driving test (pass, or fail including lessons) Secondary outcomes: cognitive tests: UFOV, complex reaction timer, Motor-Free Visual Perception Test, Single and Dot Cancellation Tests, Money Road Map Test of Direction Sense, Trail Making Tests Parts A and B, Bells test, Charron test, and Test of Everyday Attention
Notes	
Risk of bias	

Mazer 2003 (*Continued*)

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Computer-generated sequence of random numbers. Participants stratified in groups of 6 according to side of lesion and severity of visual processing deficit (mild, moderate or severe) as determined by UFOV test
Allocation concealment (selection bias)	Low risk	Allocation managed by an independent person
Incomplete outcome data (attrition bias) All outcomes	High risk	There was a large amount of missing data due to the number of participants who withdrew (17% from intervention group and 12% in the control group, 13% of participants were lost to follow-up). Stated intention-to-treat analysis performed. However, this included only randomised participants who completed the on-road test (84.5%). Secondary analyses were performed by excluding participants who did not comply with the training programme
Selective reporting (reporting bias)	Unclear risk	All outcomes and negative results reported
Other bias	Low risk	No other outcomes were recorded
Blinding of participants and personnel (performance bias) All outcomes	High risk	Participants not blinded to allocation
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Outcome assessors blinded to allocation. On-road evaluation performed prior UFOV test to prevent evaluators from observing participants performance, which may have been an indication of the intervention the participant received. Despite this, the outcome evaluator correctly identified the treatment received 79% of the time. However, this did not result in any difference in rate of passing in either groups

Mazer 2005

Methods	RCT
Participants	Rehabilitation hospital in Laval, Quebec, 2 driving evaluation centres and a private driving evaluation clinic in Montreal area, Quebec, Canada 39 participants: 20 intervention, 19 control Inclusion criteria (for stroke participants): people with a diagnosis of stroke who did not pass the driving tests at a recognised driving evaluation service. Had licence to drive and were driving prior to the stroke and desire to return to driving Exclusion criteria: medical condition precluding driving (e.g. hemianopia, seizures), received their driving evaluation more than 2 years post diagnosis, unable to communicate in English or French, inadequate communication of basic verbal instructions or judged as dangerous by the therapist in the on-road evaluation

	Mean (SD) age (years): intervention 68 (14), control 69 (9) 69% male Side of lesion: 31% left, 56.5% right Other CVA: 12.5% Mean time post stroke (years): intervention 1.4 (SD 1), control 1.7 (SD 1)
Interventions	Experimental Intervention: driving simulator. Simulator was a car frame with 3 large screens providing a large field of view. Participants were progressed through 4 increasingly complex scenarios. Level 1, participants were familiarised with the simulator and controls; level 2 involved a simulated road circuit without traffic; level 3 focused on performing different driving manoeuvres and level 4 involved a variety of traffic conditions (e.g. rain, wind, reduced visibility, pedestrians). Instant feedback was provided by the simulator when errors were made Control intervention: no intervention provided Sessions were 60 minutes, twice a week for 8 weeks (16 hours total)
Outcomes	Outcomes recorded at baseline and post intervention (or after 8 weeks for the control group) Primary outcome: DriveAble Testing Ltd Driver Evaluation - standardised driving evaluation involving a screen test and on-road evaluation (pass or fail) Secondary outcomes: cognitive tests - UFOV test, Cognitive Behavioural Drivers Inventory, Motor Free Vision perception Test, Bells test, Functional Independent Measure
Notes	Note that this study also recruited 6 people with traumatic brain injury. However, we were able to separate data for participants with stroke ; this review reports on the stroke data only

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Computer-generated sequence of random numbers. Participants stratified according to diagnosis and severity of impairment (recommended driving lessons or fail)
Allocation concealment (selection bias)	Low risk	Allocation managed by an independent person
Incomplete outcome data (attrition bias) All outcomes	High risk	7 participants, 13% (5 control, 2 simulator) did not complete the outcome evaluation and were therefore considered to have dropped out from the study Analysis was completed based on the actual number of participants contributing data and it is unclear whether intention-to-treat analyses were conducted 1 participant who did not complete the intervention was removed from the analysis
Selective reporting (reporting bias)	Low risk	All outcomes and negative results reported

Mazer 2005 (*Continued*)

Other bias	Unclear risk	Participation bias as participants may have been reluctant to enter study, particularly those with more disability and poor driving skills as results were sent to licensing agency
Blinding of participants and personnel (performance bias) All outcomes	High risk	Participants not blinded to allocation
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Outcome assessors blinded to allocation. Outcome evaluator correctly identified the participants' group allocation 64% of the time

CVA: cerebrovascular accident
RCT: randomised controlled trial
SD: standard deviation
UFOV: Useful Field of View test

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Hitosugi 2011	Study design: not an RCT
Inoue 2006	Study design: not an RCT
Jacobs 2012	Participants with stroke and brain injury
Katz 1990	Study design: not an RCT
Klavora 1995	Study design: not an RCT
Kotterba 2005	Study design: not an RCT
Lings 1991	Study design: not an RCT
Mazer 2001	Study design: not an RCT
Monning 2002	Study design: not an RCT
Schultheis 2007	Study design: not an RCT
Söderström 2006	Study design: not an RCT

RCT: randomised controlled trial

DATA AND ANALYSES

Comparison 1. Comparison of outcomes: on-road score 6 months/road sign recognition

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 On-road score 6 months	1	83	Mean Difference (IV, Random, 95% CI)	15.0 [-4.56, 34.56]
2 Road sign recognition	1	73	Mean Difference (IV, Fixed, 95% CI)	1.69 [0.51, 2.87]

Analysis 1.1. Comparison 1 Comparison of outcomes: on-road score 6 months/road sign recognition, Outcome 1 On-road score 6 months.

Review: Rehabilitation for improving automobile driving after stroke

Comparison: 1 Comparison of outcomes: on-road score 6 months/road sign recognition

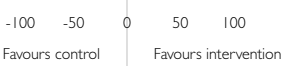
Outcome: 1 On-road score 6 months

Study or subgroup	Simulator interven-tion N	Mean(SD)	Control N	Mean(SD)	Mean Difference IV,Random,95% CI	Weight	Mean Difference IV,Random,95% CI
Akinwuntan 2005	42	167.12 (47.3)	41	152.12 (43.6)		100.0 %	15.00 [-4.56, 34.56]
Total (95% CI)	**42**		**41**			**100.0 %**	**15.00 [-4.56, 34.56]**

Heterogeneity: not applicable

Test for overall effect: Z = 1.50 (P = 0.13)

Test for subgroup differences: Not applicable

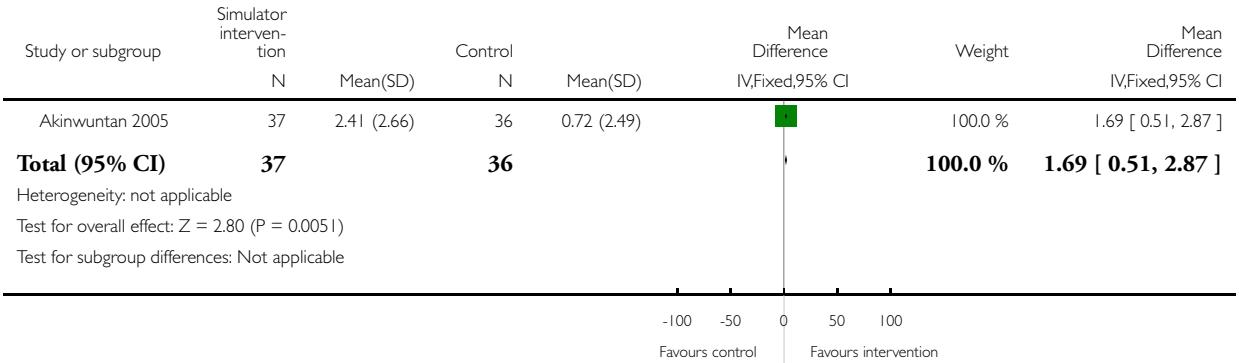


Analysis 1.2. Comparison 1 Comparison of outcomes: on-road score 6 months/road sign recognition, Outcome 2 Road sign recognition.

Review: Rehabilitation for improving automobile driving after stroke

Comparison: 1 Comparison of outcomes: on-road score 6 months/road sign recognition

Outcome: 2 Road sign recognition



ADDITIONAL TABLES

Table 1. Outcome measures used for included trials

Author and year	On-road assessment	Visual function	Cognitive function	Driving behaviour	Other
Akinwuntan 2005	Test-ride for Investigating Practical Fitness to Drive checklist	Monocular and binocular acuity Kinetic vision	Useful Field of View test Components of Stroke Driver Screening Assessment (dot cancellation, square matrix and road sign recognition test)	5 years: driving status kilometres driven self reported traffic tickets and accidents	6 months: official pre-driving assessment with licensing agency 5 years Barthel index Hospital Anxiety and Depression Scale
Crotty 2009	Standardised on-road	Visual scanning	Response speed	Driving self-efficacy	-
Mazer 2003	On-road assessment	Single and dot cancellation	Useful Field of View test Complex Reaction Timer Motor-free Visual	-	-

Table 1. Outcome measures used for included trials (*Continued*)

			Perception Test Money Road Map Test of Direction Sense Trail Making Tests Part A and B Bells test Charron test Test of Everyday Attention		
Mazer 2005	DriveAble Testing Ltd Driver Evaluation	-	Useful Field of View test Cognitive Behavioural Drivers Inventory Motor Free Vision Perception test Bells test	-	Functional Independent Measure

Table 2. Number screened, number still in trial and driving intervention at end of trial

Author and year	Screened	Randomised	Allocation intervention	Completed trial/analysed at final follow-up	Completed intervention
Akinwuntan 2005	126	83	42	73 post training 52 at 6 months 61 at 5 years	37
Crotty 2009	37	26	13	24	10
Mazer 2003	Not reported	97	47	84	39 completed 75% of intervention considered compliant
Mazer 2005	Not reported	46	22	39	20

APPENDICES

Appendix 1. Cochrane Central Register of Controlled Trials (CENTRAL) search strategy

1 cerebrovascular disorders/ or exp basal ganglia cerebrovascular disease/ or exp brain ischemia/ or exp carotid artery diseases/ or exp intracranial arterial diseases/ or exp "intracranial embolism and thrombosis"/ or exp intracranial hemorrhages/ or stroke/ or exp brain infarction/ or brain injuries/ or brain injuries, chronic/
2 (stroke or poststroke or post-stroke or cerebrovasc$ or brain vasc$ or cerebral vasc$ or cva$ or apoplex$ or SAH).tw.
3 ((brain$ or cerebr$ or cerebell$ or intracran$ or intracerebral) adj5 (isch?emi$ or infarct$ or thrombo$ or emboli$ or occlus$)).tw.
4 ((brain$ or cerebr$ or cerebell$ or intracerebral or intracranial or subarachnoid) adj5 (haemorrhage$ or hemorrhage$ or haematoma$ or hematoma$ or bleed$)).tw.
5 hemiplegia/ or exp paresis/
6 (hemipleg$ or hemipar$ or paresis or paretic or brain injur$).tw.
7 or/1-6
8 automobile driving/ or automobiles/ or motor vehicles/
9 automobile driver examination/ or accidents, traffic/
10 (driver or drivers or driving or motor vehicle$ or automobile$ or motorist$ or traffic accident$ or car accident$ or on-road assessment$).tw.
11 ((car or cars or vehicle$) adj5 drive).tw.
12 or/8-11
13 7 and 12
14 Randomized Controlled Trials as Topic/
15 random allocation/
16 Controlled Clinical Trials as Topic/
17 control groups/
18 clinical trials as topic/
19 double-blind method/
20 single-blind method/
21 cross-over studies/
22 Multicenter Studies as Topic/
23 Therapies, Investigational/
24 Research Design/
25 Program Evaluation/
26 evaluation studies as topic/
27 randomized controlled trial.pt.
28 controlled clinical trial.pt.
29 clinical trial.pt.
30 multicenter study.pt.
31 (evaluation studies or comparative study).pt.
32 random$.tw.
33 (controlled adj5 (trial$ or stud$)).tw.
34 (clinical$ adj5 trial$).tw.
35 ((control or treatment or experiment$ or intervention) adj5 (group$ or subject$ or patient$)).tw.
36 (quasi-random$ or quasi random$ or pseudo-random$ or pseudo random$).tw.
37 ((multicenter or multicentre or therapeutic) adj5 (trial$ or stud$)).tw.
38 ((control or experiment$ or conservative) adj5 (treatment or therapy or procedure or manage$)).tw.
39 ((singl$ or doubl$ or tripl$ or trebl$) adj5 (blind$ or mask$)).tw.
40 (coin adj5 (flip or flipped or toss$)).tw.
41 latin square.tw.
42 versus.tw.
43 (cross-over or cross over or crossover).tw.
44 sham.tw.
45 (assign$ or alternate or allocat$ or counterbalance$ or multiple baseline).tw.

46 controls.tw.
47 (treatment$ adj6 order).tw.
48 or/14-47
49 13 and 48
50 from 49 keep 1-43

Appendix 2. MEDLINE search strategy

1. cerebrovascular disorders/ or exp basal ganglia cerebrovascular disease/ or exp brain ischemia/ or exp carotid artery diseases/ or exp intracranial arterial diseases/ or exp "intracranial embolism and thrombosis"/ or exp intracranial hemorrhages/ or stroke/ or exp brain infarction/ or brain injuries/ or brain injuries, chronic/
2. (stroke or poststroke or post-stroke or cerebrovasc$ or brain vasc$ or cerebral vasc$ or cva$ or apoplex$ or SAH).tw.
3. ((brain$ or cerebr$ or cerebell$ or intracran$ or intracerebral) adj5 (isch?emi$ or infarct$ or thrombo$ or emboli$ or occlus$)).tw.
4. ((brain$ or cerebr$ or cerebell$ or intracerebral or intracranial or subarachnoid) adj5 (haemorrhage$ or hemorrhage$ or haematoma$ or hematoma$ or bleed$)).tw.
5. hemiplegia/ or exp paresis/
6. (hemipleg$ or hemipar$ or paresis or paretic or brain injur$).tw.
7. or/1-6
8. automobile driving/ or automobiles/ or motor vehicles/
9. automobile driver examination/ or accidents, traffic/
10. (driver or drivers or driving or motor vehicle$ or automobile$ or motorist$ or traffic accident$ or car accident$ or on-road assessment$).tw.
11. ((car or cars or vehicle$) adj5 drive).tw.
12. or/8-11
13. 7 and 12
14. Randomized Controlled Trials as Topic/
15. random allocation/
16. Controlled Clinical Trials as Topic/
17. control groups/
18. clinical trials as topic/
19. double-blind method/
20. single-blind method/
21. cross-over studies/
22. Multicenter Studies as Topic/
23. Therapies, Investigational/
24. Research Design/
25. Program Evaluation/
26. evaluation studies as topic/
27. randomized controlled trial.pt.
28. controlled clinical trial.pt.
29. (clinical trial).pt.
30. multicenter study.pt.
31. (evaluation studies or comparative study).pt.
32. random$.tw.
33. (controlled adj5 (trial$ or stud$)).tw.
34. (clinical$ adj5 trial$).tw.
35. ((control or treatment or experiment$ or intervention) adj5 (group$ or subject$ or patient$)).tw.
36. (quasi-random$ or quasi random$ or pseudo-random$ or pseudo random$).tw.
37. ((multicenter or multicentre or therapeutic) adj5 (trial$ or stud$)).tw.
38. ((control or experiment$ or conservative) adj5 (treatment or therapy or procedure or manage$)).tw.
39. ((singl$ or doubl$ or tripl$ or trebl$) adj5 (blind$ or mask$)).tw.
40. (coin adj5 (flip or flipped or toss$)).tw.

41. latin square.tw.
42. versus.tw.
43. (cross-over or cross over or crossover).tw.
44. sham.tw.
45. (assign$ or alternate or allocat$ or counterbalance$ or multiple baseline).tw.
46. controls.tw.
47. (treatment$ adj6 order).tw.
48. or/14-47
49. 13 and 48

Appendix 3. EMBASE search strategy

1 cerebrovascular disorders/ or exp basal ganglia cerebrovascular disease/ or exp brain ischemia/ or exp carotid artery diseases/ or exp intracranial arterial diseases/ or exp "intracranial embolism and thrombosis"/ or exp intracranial hemorrhages/ or stroke/ or exp brain infarction/ or brain injuries/ or brain injuries, chronic/
2 (stroke or poststroke or post-stroke or cerebrovasc$ or brain vasc$ or cerebral vasc$ or cva$ or apoplex$ or SAH).tw.
3 ((brain$ or cerebr$ or cerebell$ or intracran$ or intracerebral) adj5 (isch?emi$ or infarct$ or thrombo$ or emboli$ or occlus$)).tw.
4 ((brain$ or cerebr$ or cerebell$ or intracerebral or intracranial or subarachnoid) adj5 (haemorrhage$ or hemorrhage$ or haematoma$ or hematoma$ or bleed$)).tw.
5 hemiplegia/ or exp paresis/
6 (hemipleg$ or hemipar$ or paresis or paretic or brain injur$).tw.
7 or/1-6
8 automobile driving/ or automobiles/ or motor vehicles/
9 automobile driver examination/ or accidents, traffic/
10 (driver or drivers or driving or motor vehicle$ or automobile$ or motorist$ or traffic accident$ or car accident$ or on-road assessment$).tw.
11 ((car or cars or vehicle$) adj5 drive).tw.
12 or/8-11
13 7 and 12
14 Randomized Controlled Trials as Topic/
15 random allocation/
16 Controlled Clinical Trials as Topic/
17 control groups/
18 clinical trials as topic/
19 double-blind method/
20 single-blind method/
21 cross-over studies/
22 Multicenter Studies as Topic/
23 Therapies, Investigational/
24 Research Design/
25 Program Evaluation/
26 evaluation studies as topic/
27 randomized controlled trial/
28 controlled clinical trial/
29 clinical trial/
30 multicenter study/
31 evaluation stud$.tw.
32 comparative study/
33 random$.tw.
34 (controlled adj5 (trial$ or stud$)).tw.
35 (clinical$ adj5 trial$).tw.
36 ((control or treatment or experiment$ or intervention) adj5 (group$ or subject$ or patient$)).tw.

37 (quasi-random$ or quasi random$ or pseudo-random$ or pseudo random$).tw.
38 ((multicenter or multicentre or therapeutic) adj5 (trial$ or stud$)).tw.
39 ((control or experiment$ or conservative) adj5 (treatment or therapy or procedure or manage$)).tw.
40 ((singl$ or doubl$ or tripl$ or trebl$) adj5 (blind$ or mask$)).tw.
41 (coin adj5 (flip or flipped or toss$)).tw.
42 latin square.tw.
43 versus.tw.
44 (cross-over or cross over or crossover).tw.
45 sham.tw.
46 (assign$ or alternate or allocat$ or counterbalance$ or multiple baseline).tw.
47 controls.tw.
48 (treatment$ adj6 order).tw.
49 or/14-47
50 13 and 49
51 from 50 keep 1-611

Appendix 4. CINAHL search strategy

1. mh cerebrovascular disorders or mh basal ganglia cerebrovascular disease+ or mh brain ischemia+ or mh carotid artery diseases+ or mh intracranial arterial diseases+ or mh "intracranial embolism and thrombosis"+ or mh intracranial hemorrhages+ or stroke+ or mh brain infarction+ or mh brain injuries or brain injuries, chronic
2. TX (stroke or poststroke or post-stroke or cerebrovasc* or brain vasc* or cerebral vasc* or cva* or apoplex* or SAH)
3. (TX ((brain* n5 isch?emi*) or (brain* n5 infarct*) or (brain* n5 thrombo*) or (brain* n5 emboli*) or (brain* n5 occlus*))) or (TX ((cerebr* n5 isch?emi*) or (cerebr* n5 infarct*) or (cerebr* n5 thrombo*) or (cerebr* n5 emboli*) or (cerebr* n5 occlus*))) or (TX ((cerebell* n5 isch?emi*) or (cerebell* n5 infarct*) or (cerebell* n5 thrombo*) or (cerebell* n5 emboli*) or (cerebell* n5 occlus*))) or (TX ((intracran* n5 isch?emi*) or (intracran* n5 infarct*) or (intracran* n5 thrombo*) or (intracran* n5 emboli*) or (intracran* n5 occlus*))) or (TX ((intracerebral n5 isch?emi*) or (intracerebral n5 infarct*) or (intracerebral n5 thrombo*) or (intracerebral n5 emboli*) or (intracerebral n5 occlus*)))
4. (TX ((brain* n5 haemorrhage*) or (brain* n5 hemorrhage*) or (brain* n5 haematoma*) or (brain* n5 hematoma*) or (brain* n5 bleed*))) or (TX ((cerebr* n5 haemorrhage*) or (cerebr* n5 hemorrhage*) or (cerebr* n5 haematoma*) or (cerebr* n5 hematoma*) or (cerebr* n5 bleed*))) or (TX ((cerebell* n5 haemorrhage*) or (cerebell* n5 hemorrhage*) or (cerebell* n5 haematoma*) or (cerebell* n5 hematoma*) or (cerebell* n5 bleed*))) or (TX ((intracerebral n5 haemorrhage*) or (intracerebral n5 hemorrhage*) or (intracerebral n5 haematoma*) or (intracerebral n5 hematoma*) or (intracerebral n5 bleed*))) or (TX ((intracranial n5 haemorrhage*) or (intracranial n5 hemorrhage*) or (intracranial n5 haematoma*) or (intracranial n5 hematoma*) or (intracranial n5 bleed*))) or (TX ((subarachnoid n5 haemorrhage*) or (subarachnoid n5 hemorrhage*) or (subarachnoid n5 haematoma*) or (subarachnoid n5 hematoma*) or (subarachnoid n5 bleed*)))
5. mh hemiplegia or mh paresis +
6. TX (hemipleg* or hemipar* or paresis or paretic or brain injur*)
7. mh automobile driving or mh automobiles or mh motor vehicles
8. mh automobile driver examination or mh accidents, traffic
9. TX (driver or drivers or driving or motor vehicle* or automobile* or motorist* or traffic accident* or car accident* or on-road assessment*)
10. TX ((car n5 drive) or (cars n5 drive) or (vehicle* n5 drive))
11. "Randomized Controlled Trials"
12. mh random allocation
13. "Controlled Clinical Trials"
14. mh control groups
15. (MH "Clinical Trials")
16. mh double-blind method
17. mh single-blind method
18. mh cross-over studies
19. (MH "Multicenter Studies")

20. mh Therapies, Investigational
21. mh Research Design
22. mh Program Evaluation
23. (MH "Evaluation Research")
24. Not available as Publication Type
25. Not available as Publication Type
26. PT Clinical Trial
27. Not available as Publication Type
28. Not available as Publication Type
29. TX random*
30. TX (controlled n5 trial*) or TX (controlled n5 stud*)
31. TX (clinical* n5 trial*)
32. TX ((control n5 group*) or (control n5 subject*) or (control n5 patient*))) or (TX ((treatment n5 group*) or (treatment n5 subject*) or (treatment n5 patient*))) or (TX ((experiment* n5 group*) or (experiment* n5 subject*) or (experiment* n5 patient*))) or (TX ((intervention n5 group*) or (intervention n5 subject*) or (intervention n5 patient*)))
33. TX (quasi-random* or quasi random* or pseudo-random* or pseudo random*)
34. (TX ((multicenter n5 trial*) or (multicenter n5 stud*))) or (TX ((multicentre n5 trial*) or (multicentre n5 stud*))) or (TX ((therapeutic n5 trial*) or (therapeutic n5 stud*)))
35. (TX ((control n5 treatment) or (control n5 therapy) or (control n5 procedure) or (control n5 manage*))) or (TX ((experiment* n5 treatment) or (experiment* n5 therapy) or (experiment* n5 procedure) or (experiment* n5 manage*))) or (TX ((conservative n5 treatment) or (conservative n5 therapy) or (conservative n5 procedure) or (conservative n5 manage*)))
36. (TX ((singl* n5 blind*) or (singl* n5 mask*))) or (TX ((doubl* n5 blind*) or (doubl* n5 mask*))) or (TX ((tripl* n5 blind*) or (tripl* n5 mask*))) or (TX ((trebl* n5 blind*) or (trebl* n5 mask*)))
37. TX ((coin n5 flip) or (coin n5 flipped) or (coin n5 toss*))
38. TX latin square
39. TX versus
40. TX (cross-over or cross over or crossover)
41. TX sham
42. TX (assign* or alternate or allocat* or counterbalance* or multiple baseline)
43. TX controls
44. TX (treatment* n6 order)

Appendix 5. AMED search strategy

1 ((cerebrovascular disorders/ or exp basal ganglia cerebrovascular disease/ or exp brain ischemia/ or exp carotid artery diseases/ or exp intracranial arterial diseases/ or exp intracranial embolism/) and thrombosis/) or exp intracranial hemorrhages/ or stroke/ or exp brain infarction/ or brain injuries/ or brain injuries, chronic/
2 (stroke or poststroke or post-stroke or cerebrovasc$ or brain vasc$ or cerebral vasc$ or cva$ or apoplex$ or SAH).tw.
3 ((brain$ or cerebr$ or cerebell$ or intracran$ or intracerebral) adj5 (isch?emi$ or infarct$ or thrombo$ or emboli$ or occlus$)).tw.
4 ((brain$ or cerebr$ or cerebell$ or intracerebral or intracranial or subarachnoid) adj5 (haemorrhage$ or hemorrhage$ or haematoma$ or hematoma$ or bleed$)).tw.
5 hemiplegia/ or exp paresis/
6 (hemipleg$ or hemipar$ or paresis or paretic or brain injur$).tw.
7 or/1-6
8 automobile driving/ or automobiles/ or motor vehicles/
9 automobile driver examination/ or accidents, traffic/
10 (driver or drivers or driving or motor vehicle$ or automobile$ or motorist$ or traffic accident$ or car accident$ or on-road assessment$).tw.
11 ((car or cars or vehicle$) adj5 drive).tw.
12 or/8-11
13 7 and 12
14 Randomized Controlled Trials {No Related Terms}

15 random allocation/
16 Controlled Clinical Trials {No Related Terms}
17 control groups {No Related Terms}
18 clinical trials {No Related Terms}
19 double-blind method/
20 single-blind method/
21 cross-over studies {No Related Terms}
22 Multicenter Studies {No Related Terms}
23 Therapies, Investigational {No Related Terms}
24 Research Design {No Related Terms}
25 Program Evaluation {No Related Terms}
26 evaluation studies {No Related Terms}
27 randomized controlled trial.pt.
28 controlled clinical trial.pt.
29 clinical trial.pt.
30 multicenter study.pt.
31 (evaluation studies or comparative study).pt.
32 random$.tw.
33 (controlled adj5 (trial$ or stud$)).tw.
34 (clinical$ adj5 trial$).tw.
35 ((control or treatment or experiment$ or intervention) adj5 (group$ or subject$ or patient$)).tw.
36 (quasi-random$ or quasi random$ or pseudo-random$ or pseudo random$).tw.
37 ((multicenter or multicentre or therapeutic) adj5 (trial$ or stud$)).tw.
38 ((control or experiment$ or conservative) adj5 (treatment or therapy or procedure or manage$)).tw.
39 ((singl$ or doubl$ or tripl$ or trebl$) adj5 (blind$ or mask$)).tw.
40 (coin adj5 (flip or flipped or toss$)).tw.
41 latin square.tw.
42 versus.tw.
43 (cross-over or cross over or crossover).tw.
44 sham.tw.
45 (assign$ or alternate or allocat$ or counterbalance$ or multiple baseline).tw.
46 controls.tw.
47 (treatment$ adj6 order).tw.
48 or/14-47
49 13 and 48
50 from 49 keep 1-45

Appendix 6. PsycINFO search strategy

1 cerebrovascular disorders/ or exp basal ganglia cerebrovascular disease/ or exp brain ischemia/ or exp carotid artery diseases/ or exp intracranial arterial diseases/ or exp intracranial arteriovenous malformations/ or exp "intracranial embolism and thrombosis"/ or exp intracranial hemorrhages/ or stroke/ or exp brain infarction/
2 (stroke or poststroke or post-stroke or cerebrovasc$ or brain vasc$ or cerebral vasc$ or cva$ or apoplex$ or SAH).tw.
3 ((brain$ or cerebr$ or cerebell$ or intracran$ or intracerebral) adj5 (isch?emi$ or infarct$ or thrombo$ or emboli$ or occlus$)).tw.
4 ((brain$ or cerebr$ or cerebell$ or intracerebral or intracranial or subarachnoid) adj5 (haemorrhage$ or hemorrhage$ or haematoma$ or hematoma$ or bleed$)).tw.
5 hemiplegia/ or exp paresis/
6 (hemipleg$ or hemipar$ or paresis or paretic or brain injur$).tw.
7 or/1-6
8 automobile driving/ or automobiles/ or motor vehicles/
9 automobile driver examination/ or accidents, traffic/

10 (driver or drivers or driving or motor vehicle$ or automobile$ or motorist$ or traffic accident$ or car accident$ or on-road assessment$).tw.
11 ((car or cars or vehicle$) adj5 drive).tw.
12 or/8-11
13 7 and 12
14 Randomized Controlled Trials.mp. [mp=title, abstract, heading word, table of contents, key concepts]
15 random allocation.mp. [mp=title, abstract, heading word, table of contents, key concepts]
16 Controlled Clinical Trials.mp. [mp=title, abstract, heading word, table of contents, key concepts]
17 control groups.mp. [mp=title, abstract, heading word, table of contents, key concepts]
18 clinical trials.mp. [mp=title, abstract, heading word, table of contents, key concepts]
19 double-blind method.mp. [mp=title, abstract, heading word, table of contents, key concepts]
20 single-blind method.mp. [mp=title, abstract, heading word, table of contents, key concepts]
21 cross-over studies.mp. [mp=title, abstract, heading word, table of contents, key concepts]
22 Multicenter studies.mp. [mp=title, abstract, heading word, table of contents, key concepts]
23 Therapies.mp. [mp=title, abstract, heading word, table of contents, key concepts]
24 Research Design/
25 Program Evaluation/
26 evaluation studies.mp. [mp=title, abstract, heading word, table of contents, key concepts]
27 (controlled adj5 (trial$ or stud$)).tw.
28 (clinical$ adj5 trial$).tw.
29 ((control or treatment or experiment$ or intervention) adj5 (group$ or subject$ or patient$)).tw.
30 (quasi-random$ or quasi random$ or pseudo-random$ or pseudo random$).tw.
31 ((multicenter or multicentre or therapeutic) adj5 (trial$ or stud$)).tw.
32 ((control or experiment$ or conservative) adj5 (treatment or therapy or procedure or manage$)).tw.
33 ((singl$ or doubl$ or tripl$ or trebl$) adj5 (blind$ or mask$)).tw.
34 (coin adj5 (flip or flipped or toss$)).tw.
35 latin square.tw.
36 versus.tw.
37 (cross-over or cross over or crossover).tw.
38 sham.tw.
39 (assign$ or alternate or allocat$ or counterbalance$ or multiple baseline).tw.
40 controls.tw.
41 (treatment$ adj6 order).tw.
42 or/14-41
43 13 and 42
44 from 43 keep 1-90

Appendix 7. Risk of bias assessment tool

The Cochrane Collaboration's tool for assessing risk of bias

Domain	Description	Review authors' judgement
Sequence generation	Describe the method used to generate the allocation sequence in sufficient detail to allow an assessment of whether it should produce comparable groups	Was the allocation sequence adequately generated?

(*Continued*)

Allocation concealment	Describe the method used to conceal the allocation sequence in sufficient detail to determine whether intervention allocations could have been foreseen in advance of, or during, enrolment	Was allocation adequately concealed?
Blinding of participants, personnel and outcome assessors *Assessments should be made for each main outcome (or class of outcomes)*	Describe all measures used, if any, to blind study participants and personnel from knowledge of which intervention a participant received. Provide any information relating to whether the intended blinding was effective	Was knowledge of the allocated intervention adequately prevented during the study?
Incomplete outcome data *Assessments should be made for each main outcome (or class of outcomes)*	Describe the completeness of outcome data for each main outcome, including attrition and exclusions from the analysis. State whether attrition and exclusions were reported, the numbers in each intervention group (compared with total randomised participants), reasons for attrition/exclusions where reported, and any re-inclusions in analyses performed by the review authors	Were incomplete outcome data adequately addressed?
Selective outcome reporting	State how the possibility of selective outcome reporting was examined by the review authors, and what was found	Are reports of the study free of suggestion of selective outcome reporting?
Other sources of bias	State any important concerns about bias not addressed in the other domains in the tool. If particular questions/entries were pre-specified in the review's protocol, responses should be provided for each question/entry	Was the study apparently free of other problems that could put it at a high risk of bias?

CONTRIBUTIONS OF AUTHORS

Stacey George (guarantor of the review): conceiving, designing and co-ordinating the review; advising on search strategies; screening search results; screening retrieved papers against inclusion criteria; appraising the quality of the papers; extracting data from papers; managing and analysing the data for review; interpreting the data (providing methodological, clinical and policy perspectives); and writing the review.

Maria Crotty: conceiving, designing, and co-ordinating the review; advising on search strategies; searching for trials; interpreting the data (providing methodological, clinical and policy perspectives); and writing the review.

Isabelle Gelinas: selecting the trials; extracting data; managing and analysing the data for review; interpreting the data (providing methodological, clinical and policy perspectives); and writing the review.

Hannes Devos: selecting the trials; extracting data; managing and analysing the data for review; interpreting the data (providing methodological, clinical and policy perspectives); and writing the review.

DECLARATIONS OF INTEREST

The review authors were involved in studies that were included in the review. Such studies were appraised independently by the other review authors.

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

None.