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Electromechanical and robot-assisted arm training for improving activities of daily living, arm function, and arm muscle strength after stroke (Review)

Mehrholz J, Pohl M, Platz T, Kugler J, Elsner B

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[Intervention Review]

Electromechanical and robot-assisted arm training for improving activities of daily living, arm function, and arm muscle strength after stroke

Jan Mehrholz[1], Marcus Pohl[2], Thomas Platz[3,4], Joachim Kugler[1], Bernhard Elsner[5]

[1]Department of Public Health, Dresden Medical School, Technical University Dresden, Dresden, Germany. [2]Neurological Rehabilitation, Helios Klinik Schloss Pulsnitz, Pulsnitz, Germany. [3]Neurorehabilitation Centre and Spinal Cord Injury Unit, BDH-Klinik Greifswald, Ernst-Moritz-Arndt-Universität Greifswald, Greifswald, Germany. [4]Neurowissenschaften, Ernst-Moritz-Arndt-Universität, Greifswald, Germany. [5]Department of Public Health, Dresden Medical School, Technical University Dresden, Dresden, Germany

Contact address: Jan Mehrholz, Department of Public Health, Dresden Medical School, Technical University Dresden, Fetscherstr. 74, Dresden, 01307, Germany. jan.mehrholz@tu-dresden.de, jan.mehrholz@srh.de.

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ABSTRACT

Background

Electromechanical and robot-assisted arm training devices are used in rehabilitation, and may help to improve arm function after stroke.

Objectives

To assess the effectiveness of electromechanical and robot-assisted arm training for improving activities of daily living, arm function, and arm muscle strength in people after stroke. We also assessed the acceptability and safety of the therapy.

Search methods

We searched the Cochrane Stroke Group's Trials Register (last searched January 2018), the Cochrane Central Register of Controlled Trials (CENTRAL) (the Cochrane Library 2018, Issue 1), MEDLINE (1950 to January 2018), Embase (1980 to January 2018), CINAHL (1982 to January 2018), AMED (1985 to January 2018), SPORTDiscus (1949 to January 2018), PEDro (searched February 2018), Compendex (1972 to January 2018), and Inspec (1969 to January 2018). We also handsearched relevant conference proceedings, searched trials and research registers, checked reference lists, and contacted trialists, experts, and researchers in our field, as well as manufacturers of commercial devices.

Selection criteria

Randomised controlled trials comparing electromechanical and robot-assisted arm training for recovery of arm function with other rehabilitation or placebo interventions, or no treatment, for people after stroke.

Data collection and analysis

Two review authors independently selected trials for inclusion, assessed trial quality and risk of bias, used the GRADE approach to assess the quality of the body of evidence, and extracted data. We contacted trialists for additional information. We analysed the results as standardised mean differences (SMDs) for continuous variables and risk differences (RDs) for dichotomous variables.

Main results

We included 45 trials (involving 1619 participants) in this update of our review. Electromechanical and robot-assisted arm training improved activities of daily living scores (SMD 0.31, 95% confidence interval (CI) 0.09 to 0.52, P = 0.0005; I^2 = 59%; 24 studies, 957 participants, high-quality evidence), arm function (SMD 0.32, 95% CI 0.18 to 0.46, P < 0.0001, I^2 = 36%, 41 studies, 1452 participants, high-quality evidence), and arm muscle strength (SMD 0.46, 95% CI 0.16 to 0.77, P = 0.003, I^2 = 76%, 23 studies, 826 participants, high-quality evidence). Electromechanical and robot-assisted arm training did not increase the risk of participant dropout (RD 0.00, 95% CI -0.02 to 0.02, P = 0.93, I^2 = 0%, 45 studies, 1619 participants, high-quality evidence), and adverse events were rare.

Authors' conclusions

People who receive electromechanical and robot-assisted arm training after stroke might improve their activities of daily living, arm function, and arm muscle strength. However, the results must be interpreted with caution although the quality of the evidence was high, because there were variations between the trials in: the intensity, duration, and amount of training; type of treatment; participant characteristics; and measurements used.

PLAIN LANGUAGE SUMMARY

Electromechanical-assisted training for improving arm function and disability after stroke

Review question

To assess the effects of electromechanical and robot-assisted arm training for improving arm function in people who have had a stroke.

Background

More than two-thirds of people who have had a stroke have difficulties with reduced arm function, which can restrict a person's ability to perform everyday activities, reduce productivity, limit social activities, and lead to economic burden. Electromechanical and robot-assisted arm training uses specialised machines to assist rehabilitation in supporting shoulder, elbow, or hand movements. However, the role of electromechanical and robot-assisted arm training for improving arm function after stroke is unclear.

Study characteristics

We identified 45 trials (involving 1619 participants) up to January 2018 and included them in our review. Twenty-four different electromechanical devices were described in the trials, which compared electromechanical and robot-assisted arm training with a variety of other interventions. Participants were between 21 to 80 years of age, the duration of the trials ranged from two to 12 weeks, the size of the trials was between eight and 127 participants, and the primary outcome (activities of daily living: the most important target variable measured) differed between the included trials.

Key results

Electromechanical and robot-assisted arm training improved activities of daily living in people after stroke, and function and muscle strength of the affected arm. As adverse events, such as injuries and pain, were seldom described, these devices can be applied as a rehabilitation tool, but we still do not know when or how often they should be used.

Quality of the evidence

The quality of the evidence was high.

SUMMARY OF FINDINGS

Summary of findings for the main comparison. Electromechanical and robotic assisted training versus all other intervention for improving activities of daily living, arm function, and arm muscle strength after stroke

Electromechanical and robotic assisted training versus all other intervention for improving activities of daily living, arm function, and arm muscle strength after stroke

Patient or population: people with stroke
Settings: inpatient
Intervention: electromechanical and robotic assisted training versus all other intervention

Outcomes	Illustrative comparative risks* (95% CI)		No of Participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk			
	Control	Electromechanical and robotic assisted training versus all other intervention			
Activities of daily living at the end of intervention phase Measures of activities. Scale from: -infinity to infinity.	The mean activities of daily living at the end of intervention phase in the control groups was **2.08 FIM-Units**[1]	The mean activities of daily living at the end of intervention phase in the intervention groups was **0.31 standard deviations higher** (0.09 to 0.52 higher)	957 (24 studies)	⊕⊕⊕⊕ **high**	SMD 0.31 (0.09 to 0.52)
Activities of daily living at the end of intervention phase: subgroup analysis comparing acute and chronic phase - Participants treated in the acute and subacute phase of their stroke (within 3 months) Measures of activities. Scale from: -infinity to infinity.	The mean activities of daily living at the end of intervention phase: subgroup analysis comparing acute and chronic phase - participants treated in the acute and subacute phase of their stroke (within 3 months) in the control groups was **2.69 FIM-Units**[1]	The mean activities of daily living at the end of intervention phase: subgroup analysis comparing acute and chronic phase - participants treated in the acute and subacute phase of their stroke (within 3 months) in the intervention groups was **0.4 standard deviations higher** (0.1 to 0.7 higher)	532 (13 studies)	⊕⊕⊕⊕ **high**	SMD 0.4 (0.1 to 0.7)
Activities of daily living at the end of intervention phase: subgroup analysis comparing acute and chronic phase - Participants treated in the chronic phase (more than 3 months)	The mean activities of daily living at the end of intervention phase: subgroup analysis comparing acute and chronic phase - participants treated in the chronic	The mean activities of daily living at the end of intervention phase: subgroup analysis comparing acute and chronic phase - participants treated in the chronic phase (more than 3 months) in the intervention groups was	425 (11 studies)	⊕⊕⊕⊕ **high**	SMD 0.56 (-0.23 to 1.35)

Measures of activity. Scale from: -infinity to infinity.	phase (more than 3 months) in the control groups was **1.28 FIM-Units**[1]	**0.56 standard deviations higher** (0.23 lower to 1.35 higher)			
Arm function at the end of intervention phase Upper Extremity Fugl-Meyer Assessment (UE-FM). Scale from: -infinity to infinity.	The mean arm function at the end of intervention phase in the control groups was **1.59 UE-FM Units**[1]	The mean arm function at the end of intervention phase in the intervention groups was **0.32 standard deviations higher** (0.18 to 0.46 higher)	1452 (41 studies)	⊕⊕⊕⊕ **high**	SMD 0.32 (0.18 to 0.46)
Arm muscle strength at the end of intervention phase Measures of arm muscle strength. Scale from: -infinity to infinity.	The mean arm muscle strength at the end of intervention phase in the control groups was **2.83 MRC grades of strength**[1]	The mean arm muscle strength at the end of intervention phase in the intervention groups was **0.46 standard deviations higher** (0.16 to 0.77 higher)	826 (23 studies)	⊕⊕⊕⊕ **high**	SMD 0.46 (0.16 to 0.77)
Acceptability: drop-outs during intervention period Numbers of dropouts and adverse events	**57 per 1000**	**56 per 1000** (37 to 77)	1619 (45 studies)	⊕⊕⊕⊕ **high**	Risks were calculated from pooled risk differences

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).
CI: Confidence interval; **RR:** Risk ratio;

GRADE Working Group grades of evidence
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

[1] Backtransformed SMD by using the standard deviation of a familiar outcome measure of the control group taken from a study with low risk of bias

BACKGROUND

Description of the condition

A stroke is a sudden, nonconvulsive loss of neurological function due to an ischaemic or haemorrhagic event in the brain (WHO 2006). In general, strokes are classified by anatomic location in the brain, vascular distribution, aetiology, age of the affected individual, and haemorrhagic versus nonhaemorrhagic nature (Adams 1993). The prevalence of stroke depends on age and gender, and is estimated to be 1% of the population (Feigin 2009; Vos 2015). Stroke, taken together with ischaemic heart disease, is one of the largest sources of disease burden; in low- and middle-income countries of Europe and Central Asia, these conditions account for more than a quarter of the total disease burden (Vos 2015).

Stroke is a major cause of chronic impaired arm function and may affect many activities of daily living. At hospital admission after stroke, more than two-thirds of people have arm paresis (and therefore have limited hand-arm function), resulting in reduced upper extremity function (Jørgensen 1999; Nakayama 1994), and six months after stroke the affected arm of approximately half of all people remains without function (Kwakkel 2003). Therefore, to reduce this burden, many people receive multidisciplinary rehabilitation soon after stroke. However, despite intensive rehabilitation efforts, only approximately 5% to 20% of people reach complete functional recovery (Nakayama 1994); in other words, four out of five people leave rehabilitation with restricted arm function. Thus, there still exists an urgent need for new inpatient and outpatient rehabilitation and training strategies that match the specific needs of stroke survivors and their relatives (Barker 2005).

Description of the intervention

In recent years, new electromechanical-assisted training strategies to improve arm function and activities of daily living have been developed for people after stroke. Examples of electromechanical and robot-assisted arm training devices found in this review are:

- Mirror Image Motion Enabler, MIME (Burgar 2000);
- InMotion robot (Massachusetts Institute of Technology, MIT-Manus) (Krebs 1998);
- Assisted Rehabilitation and Measurement (ARM) Guide (Reinkensmeyer 2000b);
- Robotic Rehabilitation System for upper limb motion therapy for the disabled, REHAROB (Fazekas 2007);
- Neuro-Rehabilitation-Robot, NeReBot (Fazekas 2007);
- Bi-Manu-Track (Hesse 2003);
- Robot-mediated therapy system, GENTLE/s (Coote 2003);
- Arm robot, ARMin (Riener 2005); and
- Amadeo (Hwang 2012).

Most of these devices provide passive movement of the person's arm. Other devices assist arm movements or provide resistance during training. Some devices may assist active movements of an isolated joint, like in continuous passive motion (Hesse 2003), while other devices are able to move multiple segments to perform reaching-like movements (Burgar 2000). The progression of therapy with electromechanical devices is possible by, for example, varying the force, decreasing assistance, increasing resistance, and expanding the movement amplitude. Moreover, some devices, such as the Bi-Manu-Track and the MIME, may be used to provide bimanual exercise: the device simultaneously moves (mirrors) the affected limb passively, steered by the non-paretic limb. Broadly considered, most robotic systems incorporate more than one modality into a single device.

How the intervention might work

Early studies and previous reviews suggested that an advantage of electromechanical and robotic devices, when compared with conventional therapies, may be an increase in repetitions during arm training due to an increase of motivation to train and also the opportunity for independent exercise (Kwakkel 2008; Prange 2006). Therefore, electromechanical-assistive training devices allow a therapy paradigm that is intensive, frequent and repetitive, and accords with principles of motor learning.

Why it is important to do this review

Given the remarkable number of publications about electromechanical technologies, frequently from studies with smaller samples, there is a necessity to summarise and characterise the scientific evidence for the benefits and risks of these technologies for clinical decision making, keeping in mind the implied resource use for this type of therapy. We summarised the evidence in our first Cochrane review about this topic in 2008 and in our last update in 2015 (Mehrholz 2008; Mehrholz 2015), but many new studies have emerged in recent years. There is, therefore, a need for an updated and systematic evaluation of the available literature to assess the effectiveness and acceptability of these electromechanical-assisted training devices.

OBJECTIVES

To assess the effectiveness of electromechanical and robot-assisted arm training for improving activities of daily living, arm function, and arm muscle strength in people after stroke. We also assessed the acceptability and safety of the therapy.

METHODS

Criteria for considering studies for this review

Types of studies

We included randomised controlled trials (RCTs) and randomised controlled cross-over trials (we only analysed the first study period as a parallel-group trial).

Types of participants

We included studies with participants of either gender over 18 years of age after stroke (using the World Health Organization (WHO) definition of stroke, or a clinical definition of stroke when the WHO definition was not specifically stated) (WHO 2006), regardless of the duration of illness or level of initial impairment. If we found RCTs with mixed populations (such as traumatic brain injury and stroke), we included only those RCTs with more than 50% of participants with stroke in our analysis.

Although we initially included all studies regardless of the duration of illness in our analysis, we later separately analysed and compared therapeutic effectiveness for participants in the acute and subacute phase of their stroke (within three months) and participants in the chronic phase (more than three months) in a

planned subgroup analysis. The responsiveness to therapy might well differ earlier and later after stroke and clinical decision making would benefit from this information.

Types of interventions

We compared electromechanical and robot-assisted arm training for recovery of arm function (such as robot-aided technologies or any other newly-developed electromechanical device) with any other intervention for:

- improving activities of daily living (main analysis); and
- improving impairments (secondary analysis).

An example of an eligible robot-assisted intervention is the Mirror Image Motion Enabler, MIME (Burgar 2000). An example of an electromechanical-assisted intervention is the Bi-Manu-Track (Hesse 2003). Other interventions could include other devices, other rehabilitation or placebo interventions, or no treatment.

Types of outcome measures

Primary outcomes

The primary outcome was activities of daily living. We preferred the Barthel Index (Wade 1987), and the Functional Independence Measure (Hamilton 1994) as primary outcome measures (scales were regarded as continuously scaled, with higher scores indicating a good outcome), if they were available. However, we accepted other scales that measured activities of daily living.

Secondary outcomes

The secondary outcomes were impairments, such as motor function and muscle strength. We measured arm motor function with the Fugl-Meyer score (regarded as continuously scaled, with higher scores indicating a good outcome; Platz 2005), and measured arm muscle strength with the Motricity Index Score (scales were regarded as continuously scaled, with higher scores indicating a good outcome; Collin 1990; Demeurisse 1980). However, if these scales were not available, we accepted other scales that measured arm and hand function and arm and hand muscle strength (in this review we will use the term 'arm function' instead of 'arm and hand function' and also 'arm muscle strength' instead of 'arm and hand muscle strength').

To measure the acceptance of electromechanical and robot-assisted arm training, we used withdrawal or dropouts from the study due to any reason (including deaths) during the study period. We investigated the safety of electromechanical and robot-assisted arm training with the incidence of adverse outcomes, such as cardiovascular events, injuries and pain, and any other reported adverse events.

Depending on the aforementioned categories and the availability of variables used in the included trials, all review authors discussed and reached consensus on which outcome measures should be included in the analysis.

Search methods for identification of studies

See the 'Specialized register' information at the Cochrane Stroke Group's website. We did not restrict our searches by language, publication status, or date, and we arranged for the translation of articles, where necessary.

Electronic searches

We searched the Cochrane Stroke Group Trials Register (last searched on 22 January 2018) and the following bibliographic databases:

- Cochrane Central Register of Controlled Trials (CENTRAL; 2018, Issue 1) in the Cochrane Library (searched 22 January 2018) (Appendix 1);
- MEDLINE (Ovid) (1950 to 22 January 2018) (Appendix 2);
- Embase (Ovid) (1980 to 22 January 2018) (Appendix 3);
- CINAHL (Ebsco) (1982 to 22 January 2018) (Appendix 4);
- AMED (Allied and Complementary Medicine) (Ovid) (1985 to 22 January 2018) (Appendix 5);
- SPORTDiscus (Ebsco) (1949 to 22 January 2018) (Appendix 6);
- Physiotherapy Evidence Database (PEDro, www.pedro.org.au/) (searched 2 February 2018) (Appendix 7);
- Compendex (1972 to 23 January 2018) and Inspec (1969 to 23 January 2018) (Engineering Village) (Appendix 8).

We developed the search strategy for MEDLINE with the help of the Cochrane Stroke Group Information Specialist and modified it for the other databases.

We identified and searched the following ongoing trials and research registers:

- ISRCTN Registry (www.isrctn.com/) (searched 23 January 2018) (Appendix 9);
- US National Institutes of Health Ongoing Trials Register ClinicalTrials.gov (www.clinicaltrials.gov; 23 January 2018) (Appendix 10);
- Stroke Trials Registry (www.strokecenter.org/trials) (searched 23 January 2018) (Appendix 11);
- World Health Organization International Clinical Trials Registry Platform (apps.who.int/trialsearch; searched 23 January 2018) (Appendix 12).

Searching other resources

In an effort to identify further published, unpublished, and ongoing trials not available in the major databases, we:

- handsearched the following relevant conference proceedings:
  - World Congress for NeuroRehabilitation (WCNR, 1998, 2002, 2006, 2010, and 2014);
  - International Society of Physical and Rehabilitation Medicine World Congress (ISPRM 2001 to 2017);
  - World Confederation for Physical Therapy (2003, 2007, 2011, 2015 and 2017);
  - International Congress on Neurorehabilitation and Neural Repair (2015 and 2017);
  - Deutsche Gesellschaft für Neurotraumatologie und Klinische Neurorehabilitation (2001 to 2017);
  - Deutsche Gesellschaft für Neurologie (2000 to 2017);
  - Deutsche Gesellschaft für Neurorehabilitation (1999 to 2017);
- screened reference lists of all relevant articles;
- contacted trialists, experts, and researchers in our field of study; and

- contacted the following manufacturers of commercial devices:
  * Hocoma (last contact December 2017); and
  * Reha-Stim (last contact December 2017).

Data collection and analysis

Selection of studies

Two review authors (JM and BE) independently read the titles and abstracts (if available) of identified publications and eliminated obviously irrelevant studies. We obtained the full-text articles for the remaining studies, and the same two review authors independently examined potentially relevant studies using our predetermined criteria for including studies. Based on types of studies, participants, aims of interventions, and outcome measures, the review authors independently ranked these studies as relevant, irrelevant, or possibly relevant. We excluded all trials ranked initially as irrelevant, but included all other trials at that stage for further assessment. We excluded all trials of specific treatment components (such as electrical stimulation) as standalone treatment, continuous passive motion treatment and continuous passive stretching. All review authors resolved disagreements through discussion. If further information was needed to reach consensus, we contacted the study authors.

Data extraction and management

Two review authors (JM and MP) independently extracted trial and outcome data from the selected trials. We used checklists to independently record details of the studies. If any review author was involved in any of the selected studies, we asked another member of our review team not involved in the study to handle the study information.

We established the characteristics of unpublished trials through correspondence with the trial coordinator or principal investigator. We used checklists to independently record details of the:

- methods of generating randomisation schedule;
- method of concealment of allocation;
- blinding of assessors;
- use of an intention-to-treat analysis (all participants initially randomised were included in the analyses as allocated to groups);
- adverse events and dropouts for all reasons;
- important imbalance in prognostic factors;
- participants (country, number of participants, age, gender, type of stroke, time from stroke onset to entry to the study, inclusion and exclusion criteria);
- comparison (details of the intervention in treatment and control groups, details of cointervention(s) in both groups, duration of treatment); and
- outcomes and time points of measures (number of participants in each group and outcome, regardless of compliance).

We checked all of the extracted data for agreement between review authors, with another review author (JK or BE) arbitrating any disagreements. We contacted study authors to request more information, clarification, or missing data, if necessary.

Assessment of risk of bias in included studies

All review authors independently assessed the methodological quality of the included trials using the Cochrane 'Risk of bias' tool, as described in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2017).

We checked all methodological quality assessments for agreement between review authors, resolving any disagreements by discussion. Two review authors (MP and JM) were co-authors of one included trial (Hesse 2005); two other review authors (BE and JK) conducted the quality assessment for this trial.

Measures of treatment effect

We treated the primary outcome variables of interest as continuous data and entered them as mean and standard deviations (SDs). We pooled data and planned to calculate the mean differences (MDs) with 95% confidence intervals (CIs). If studies used different scales for an outcome variable, or if we obtained only full data of any included studies regarding changes from baseline to study end, we entered data as mean changes and SDs of changes and used the standardised mean difference (SMD) with 95% CI instead of MDs. For all binary outcomes (such as the secondary outcome 'dropouts from all causes'), we pooled data and planned to calculate risk ratios (RRs) with 95% CIs. If studies reported no events, we pooled data and calculated risk differences (RDs) with 95% CIs, instead of RRs.

Unit of analysis issues

In the event that individuals underwent more than one intervention, as in a cross-over trial, we only used data from the first phase of the study before cross-over.

If outcomes were repeatedly observed in participants (e.g. at the of intervention at four and six weeks), we reported the measures at the longest time point post intervention from each study.

Dealing with missing data

We contacted the relevant principal investigators to retrieve missing data. Where possible, we extracted data to allow an intention to-treat (ITT) analysis in which all randomised participants were analysed in the groups to which they were originally assigned. We did not make assumptions about loss to follow-up for continuous data. We analysed results for those who completed the trial.

Assessment of heterogeneity

We used the I^2 statistic to assess heterogeneity. We used a random-effects model, regardless of the level of heterogeneity. We investigated heterogeneity with creating subgroups and undertaking sensitivity analyses. Additionally, we looked for extreme outliers in our forest plots to see if there was something different about the trials with markedly different results from the others.

Assessment of reporting biases

We inspected funnel plots for all outcomes and subgroup analysis in order to assess the risk of publication bias.

Data synthesis

We pooled the results of all eligible studies to present an overall estimate of the effect of electromechanical and robot-assisted arm training (meta-analysis). For all statistical analyses, we used the latest version of the Cochrane Review Manager software (RevMan 2014). We calculated the overall effects using a random-effects model, regardless of the level of heterogeneity. To test the robustness of the results, we did a sensitivity analysis by leaving out studies that we assessed to be of lower or ambiguous methodological quality (with respect to randomisation procedure, allocation concealment, and blinding of assessors). Clinical diversity and heterogeneity did not contribute to the decision about when to pool trials, but we described clinical diversity, and variability in participants, interventions, and outcomes studied in Table 1.

If studies had three or more intervention groups, for example two treatment groups and one control group, and the results of these intervention groups did not differ significantly, we combined the results of all intervention groups in one (collapsed) group and compared this with the results of the control group.

GRADE and Summary of findings

We assessed the quality of evidence by using the five GRADE considerations (study limitations, consistency of effect, imprecision, indirectness and publication bias). We assessed overall quality of the evidence as either high, moderate, low, or very low (Higgins 2017).

We also included a Summary of findings table for the main comparison of electromechanical and robot-assisted arm training for recovery of arm function (such as robot-aided technologies or any other newly developed electromechanical device) with any other intervention for the outcomes of:

- activities of daily living at the end of intervention phase: measures of activities;
- activities of daily living at the end of intervention phase: subgroup analysis comparing acute and chronic phase - participants treated in the acute and subacute phase of their stroke (within three months);
- activities of daily living at the end of intervention phase: subgroup analysis comparing acute and chronic phase - participants treated in the chronic phase (more than three months);
- arm function at the end of intervention phase;
- arm muscle strength at the end of intervention phase;
- acceptability: numbers of dropouts and adverse events during intervention period.

Subgroup analysis and investigation of heterogeneity

We did a comparison between the results of the primary outcome measure of participants treated in the acute and subacute phase of their stroke and the results of participants treated in the chronic phase (Deeks 2011).

We conducted another subgroup analysis by splitting all participants into three subgroups: 1) a subgroup of participants who received mainly training for the distal arm and the hand (finger, hand, and radio-ulnar joints); 2) a subgroup of participants who received training mainly of the proximal arm (shoulder and elbow joints); and 3) a subgroup of participants treated in the chronic phase (more than three months after stroke). In this subgroup analysis, we did a formal comparison between the results of the subgroups for the primary outcome measure (activities of daily living) and the secondary outcome measure (arm function). To quantify heterogeneity, we used the I^2 statistic implemented in RevMan for all comparisons (RevMan 2014). Additionally, we searched and attempted to identify reasons for outliers in our forest plots.

Sensitivity analysis

In accordance with the description in the *Cochrane Handbook for Systematic Reviews of Interentions*, we used the methodological features of randomisation procedure, concealed allocation, and blinding of assessors to test the robustness of the main results in a sensitivity analysis (Higgins 2017).

RESULTS

Description of studies

See: Characteristics of included studies, Characteristics of excluded studies, Characteristics of ongoing studies, Table 1, and Table 2.

Results of the search

Our updated searches of the electronic bibliographic databases identified 4802 citations (Figure 1). One review author (BE) carried out additional searches of trials registers, commercial websites, conference proceedings, and reference lists, and from these and the search of the Cochrane Stroke Group's Trials Register, we identified one further study for inclusion. Hence, the number of records identified was 4803. After the elimination of duplicates, two review authors (BE and JM) assessed 2708 unique abstracts and eliminated obviously irrelevant studies from the titles and abstracts alone. We obtained the full text of 59 possibly relevant papers. The same review authors (BE and JM) independently reviewed the full papers and selected 11 studies (16 full texts) that met our inclusion criteria. If necessary, due to disagreements or uncertainties, we held consensus discussions involving additional review authors. We carefully considered and discussed a further six studies, but did not deem them eligible; we have detailed them in Characteristics of excluded studies.

Figure 1. Study flow diagram. Please note that several studies have been published in multiple full-text articles. Hence the number of assessed full-text articles and the number of identified studies may differ.

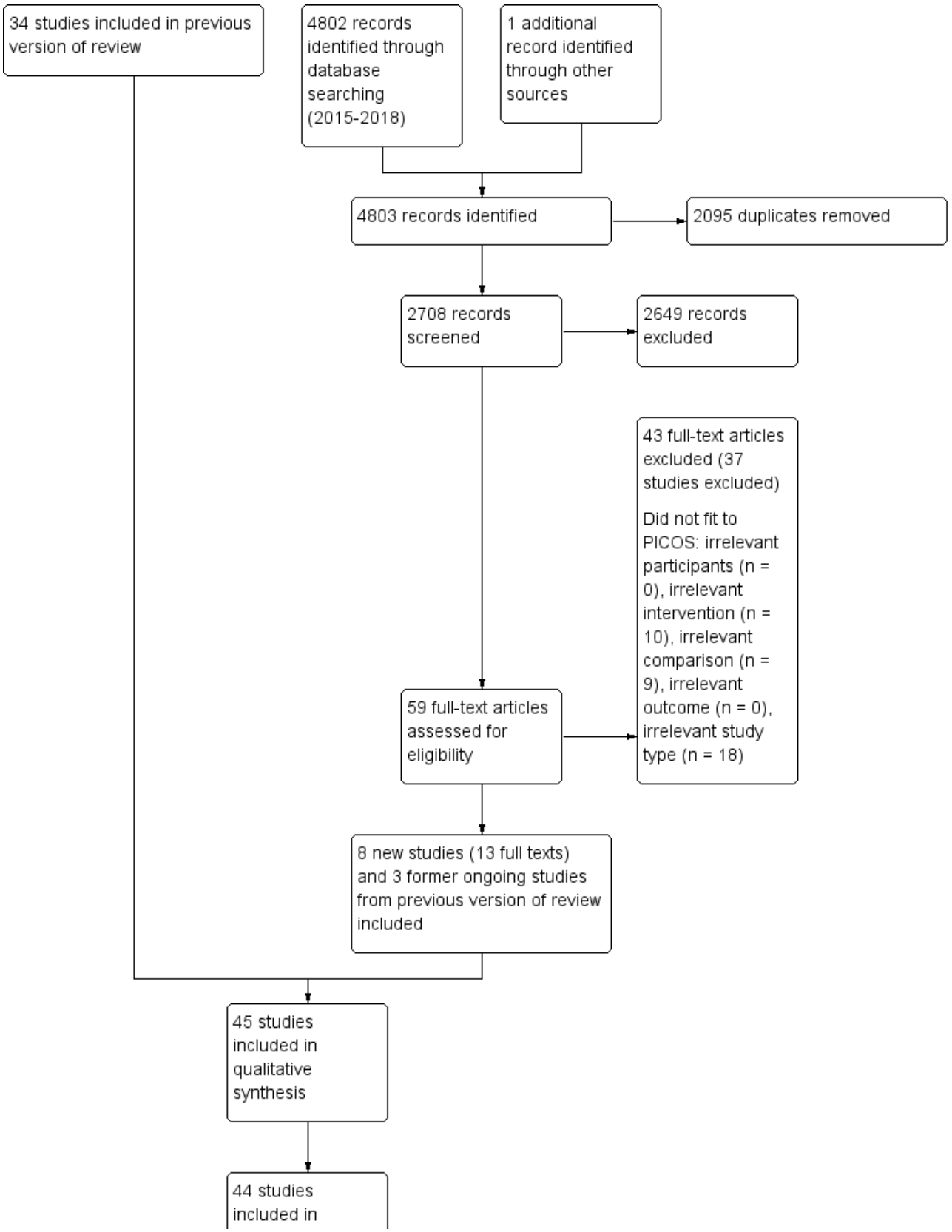
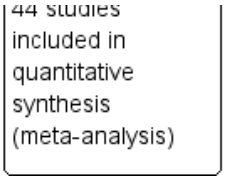


Figure 1. (Continued)



We thus identified 11 new studies (16 full texts), and together with 34 studies included in the original review, we have included a total of 45 studies in this update. Seven studies are still awaiting classification; we have described these studies in detail in Characteristics of studies awaiting classification. In addition, we identified 23 ongoing studies, which we have listed in Characteristics of ongoing studies.

Included studies

Forty-five trials, including a total of 1615 participants, met our inclusion criteria and have been included in the analysis (see Figure 1, Characteristics of included studies, Table 1, and Table 2).

Design

Two trials used a cross-over design with random allocation to the order of treatment sequences (Amirabdollahian 2007; Hollenstein 2011). For Amirabdollahian 2007, we could not obtain outcome data from the trialists of this study, therefore we could not pool the data for this trial together with the data from other studies. In Hollenstein 2011, we used the data of the first period before cross-over. All other studies used a parallel-group design with true randomisation-to-group allocation.

Sample sizes

The sample sizes in the trials ranged from eight participants in Mayr 2008, to 127 participants in Lo 2010. We have provided a more detailed description of trial characteristics in Characteristics of included studies and in Table 1 and Table 2.

Setting

Most of the trials were done in rehabilitation facilities in the USA. We have provided a more detailed description of trial characteristics in Characteristics of included studies.

Participants

The mean age of participants in the included studies ranged from 21 years in McCabe 2015, to 80 years in Rabadi 2008. We have provided a detailed description of participant characteristics in Table 1. There were significantly more males than females, and slightly more participants with left-sided hemiparesis (Table 1) included in the studies.

Thirty-four studies provided information about baseline stroke severity (for example, Functional Independence Measure, Barthel) or about the deficit of arm motor function (Fugl-Meyer) (Table 1).

For inclusion and exclusion criteria of every included study, see Characteristics of included studies.

Interventions

The duration of the studies (time frame where experimental interventions were applied) was heterogeneous, ranging from two weeks in Hollenstein 2011, and three weeks in Amirabdollahian 2007 and Burgar 2011, to 12 weeks (Brokaw 2014; Daly 2005; Lo 2010; Table 2). Some studies (15 out of 45) used a study intervention period of two, three, four, or six weeks (Table 2). The studies described and used 19 different electromechanical devices (see Table 2 for an overview); the devices used most often were the Bi-Manu-Track (Hesse 2005; Hesse 2014; Hsieh 2011; Hsieh 2014; Liao 2011; Wu 2012), the InMotion (Conroy 2011; Daly 2005; McCabe 2015; Volpe 2008), and the MIT-Manus (Lo 2010; Rabadi 2008; Sale 2014; Volpe 2000).

Comparisons

The included trials compared electromechanical and robot-assisted arm training with a variety of other interventions. We did a formal meta-analysis only of studies that measured the same treatment effect. Thus, we combined electromechanical and robot-assisted arm training versus placebo (or no additional therapy) (two studies) with electromechanical and robot-assisted arm training combined with physiotherapy versus physiotherapy alone (41 studies), as both estimated the effect of electromechanical and robot-assisted arm training compared with a different treatment. However, we did not combine study arms such as electromechanical and robot-assisted arm training versus physiotherapy (or no treatment) with electromechanical and robot-assisted arm training A versus electromechanical and robot-assisted arm training B, as these all measured entirely different treatment effects.

One study had four groups: three treatment (robot) groups and one control group (Lum 2006). Since the results of these experimental groups did not differ significantly, we combined the results of all experimental groups into one robot (collapsed) group and compared this with the results of the control group. Nine other studies used three arms: two treatment (robot) groups and one control group or two control and one treatment group (Ang 2014; Burgar 2011; Conroy 2011; Hsieh 2011; Hsieh 2014; Lo 2010; McCabe 2015; Rabadi 2008; Wu 2012). As we were interested in the effects of robot therapy versus any other control intervention, we either combined the results of both experimental groups in one (collapsed) group and compared this with the results of the control group, or we combined the results of both control groups in one (collapsed) group and compared this with the results of the one treatment group.

For most trials, the frequency of treatment was five times per week (see Table 2 for a detailed description of time and frequency for each single study).

The intensity of treatment (in terms of duration of experimental therapy provided) ranged from 20 minutes in Masiero 2011, or 30 minutes in Fazekas 2007, Hesse 2005 and Masiero 2007, to 90 minutes each working day in Daly 2005 and Hsieh 2011, or even 90 to 105 minutes each day (Hsieh 2014). For some studies, the intensity of the experimental treatment was still unclear (Amirabdollahian 2007; Kahn 2006; Lo 2010). We have provided a detailed description for each single study in Table 2 and a more detailed description of the individual therapy in studies in Characteristics of included studies.

Outcomes

The primary outcomes of the included studies varied. See Characteristics of included studies for a detailed description of the primary outcomes for each trial.

In our pooled analysis for the primary outcome, activities of daily living, we used the Barthel Index score or the modified Barthel Index (Hesse 2005; Hesse 2014; Lee 2016; NCT03020576; Tomic 2017; Villafane 2017; Yoo 2013), the Functional Independence Measure (Burgar 2011; Fazekas 2007; Lum 2006; Masiero 2007; Takahashi 2016; Taveggia 2016; Volpe 2000), the ABILHAND (Hsieh 2011; Liao 2011), the Stroke Impact Scale 3.0 (motor function and social participation section) (Kutner 2010; Lo 2010; Wu 2012), the Stroke Impact Scale 2.0 (higher scores indicated a good outcome) (Volpe 2008), and the Frenchay Arm Test (Masiero 2011).

For our secondary outcome of arm function, we used the Fugl-Meyer score or the Chedoke-McMaster Stroke Assessment (Abdullah 2011; Mayr 2008), and, in one study, the Wolf Motor Function Test for our pooled analysis; we conducted a separate analysis for impaired arm function (Yoo 2013). For our secondary outcome of arm strength, we accepted measures such as the Motricity Index score or Medical Research Council score (higher scores indicated a good outcome) or grip force.

All included studies assessed outcomes at the end of the study, but the follow-up assessment varied between three months and nine months after study end (see Table 2 for a detailed description of time points of assessment for each single study). As reporting data of follow-up measures were heterogeneous and limited mostly to our primary outcome, we did not conduct separate analyses for immediate data after study end and sustained data from follow-up after study end. We, therefore, undertook just one analysis (immediately after the end of the intervention).

Excluded studies

We excluded 33 trials (15 full texts) (see Characteristics of excluded studies for reasons for exclusion) from the current update. If there was any doubt about whether or not a study should be excluded, we retrieved the full text of the article. Where the two review authors (BE and JM) disagreed, a third review author (JK) decided on inclusion or exclusion of a study.

Ongoing studies

We identified 23 ongoing studies (see Ongoing studies), which we have described in Characteristics of ongoing studies. Eight of these studies were listed as ongoing studies in the previous version of the review. After we retrieved further information, three of the original ongoing studies became included studies.

Risk of bias in included studies

Two authors (JM and ST) independently assessed the methodological quality of the included trials using the Cochrane 'Risk of bias' tool (using the categories, random sequence generation, allocation concealment, and blinding of outcome assessors; Figure 2). We have provided all details about the methodological quality of each included study in Characteristics of included studies. We wrote to the trialists of all the included studies requesting clarification of some design features or missing information in order to complete the quality ratings. The correspondence was via email or letter, and we wrote reminders every month if we did not receive an answer. Most trialists provided some or all of the requested data, but we did not receive all requested data for four trials. If no data were provided or no contact achieved, we used published data only for all analysis.

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

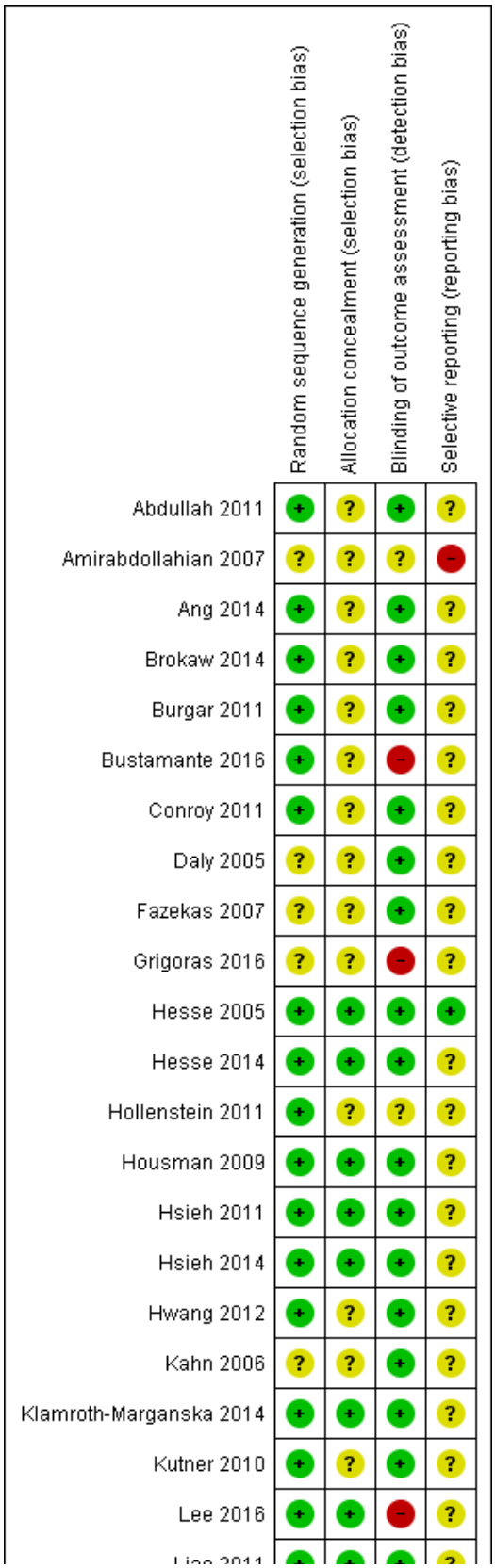
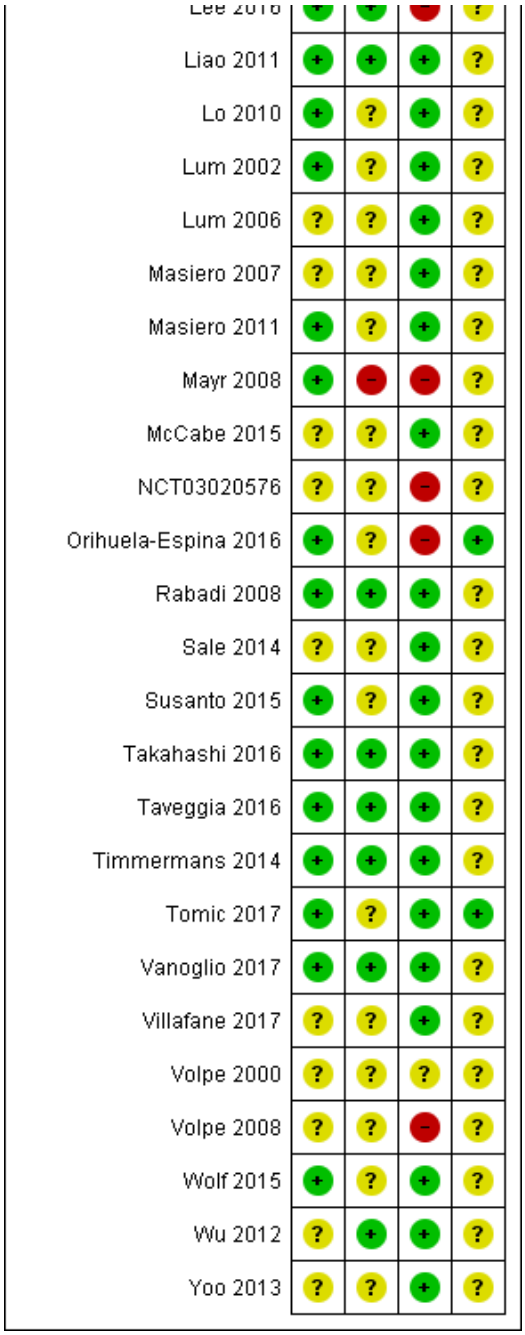


Figure 2. (Continued)



Allocation

Thirty of the 45 included studies described appropriately the method of random sequence generation, and we, therefore, judged them to be at low risk of bias (Figure 2).

Fifteen of the 45 included studies described random sequence generation but the method used was unclear, and we, therefore, judged these studies to be at unclear risk of bias (Figure 2).

No study described no random sequence generation and we, therefore, judged no study to be at high risk of bias.

Fourteen of the 45 included studies described appropriately the method of concealing allocation of participants to groups, and we, therefore, judged them to be at low risk of bias (Figure 2).

Thrity of the 45 included studies did not described the method of concealing allocation of participants to groups appropriately, and we, therefore, judged them to be at unclear risk of bias (Figure 2).

One of the 45 included studies described did not have an appropriate method of concealing allocation of participants to groups, and we, therefore, judged it to be at high risk of bias (Figure 2).

Blinding

Thirty-five of the 45 included studies described the outcome assessors as being blinded to group allocation. Where there was adequate method of blinding the outcome assessors, we judged the studies to be at low risk of bias (Figure 2).

Three of the 45 included studies did not described appropriately the outcome assessors as being blinded to group allocation, and we, therefore, judged them to be at unclear risk of bias (see Figure 2 and Characteristics of included studies for detailed reasons).

Seven of the 45 included studies did not blind the outcome assessors to group allocation, and we, therefore, judged them to be at high risk of bias (see Figure 2 and Characteristics of included studies for detailed reasons).

Incomplete outcome data

Three of the 45 included studies described incomplete outcome data; however, the dropouts appeared not to be substantial. The dropouts were balanced between the groups and therefore did not appear to indicate potential bias.

There was no appropriate, or an unclear, description of handling incomplete outcome data in 41 of the 45 studies (see Figure 2 and Characteristics of included studies for detailed reasons); we considered them to be at unclear risk of bias for this domain of bias.

No description of handling incomplete outcome data was available in one study (Amirabdollahian 2007), and after contacting the principal investigators, we considered this study to be at high risk of bias for this domain.

Selective reporting

For the majority of studies, particularly the older trials, we could not find study protocols. In these cases, we assessed whether all the outcomes listed in the methods section of the publication were then reported in the results section. In most cases, where these study protocols were available, there was no evidence of selective reporting of outcomes relevant to this review.

Other potential sources of bias

We were not aware of other potential sources of bias.

Effects of interventions

See: **Summary of findings for the main comparison** Electromechanical and robotic assisted training versus all other intervention for improving activities of daily living, arm function, and arm muscle strength after stroke

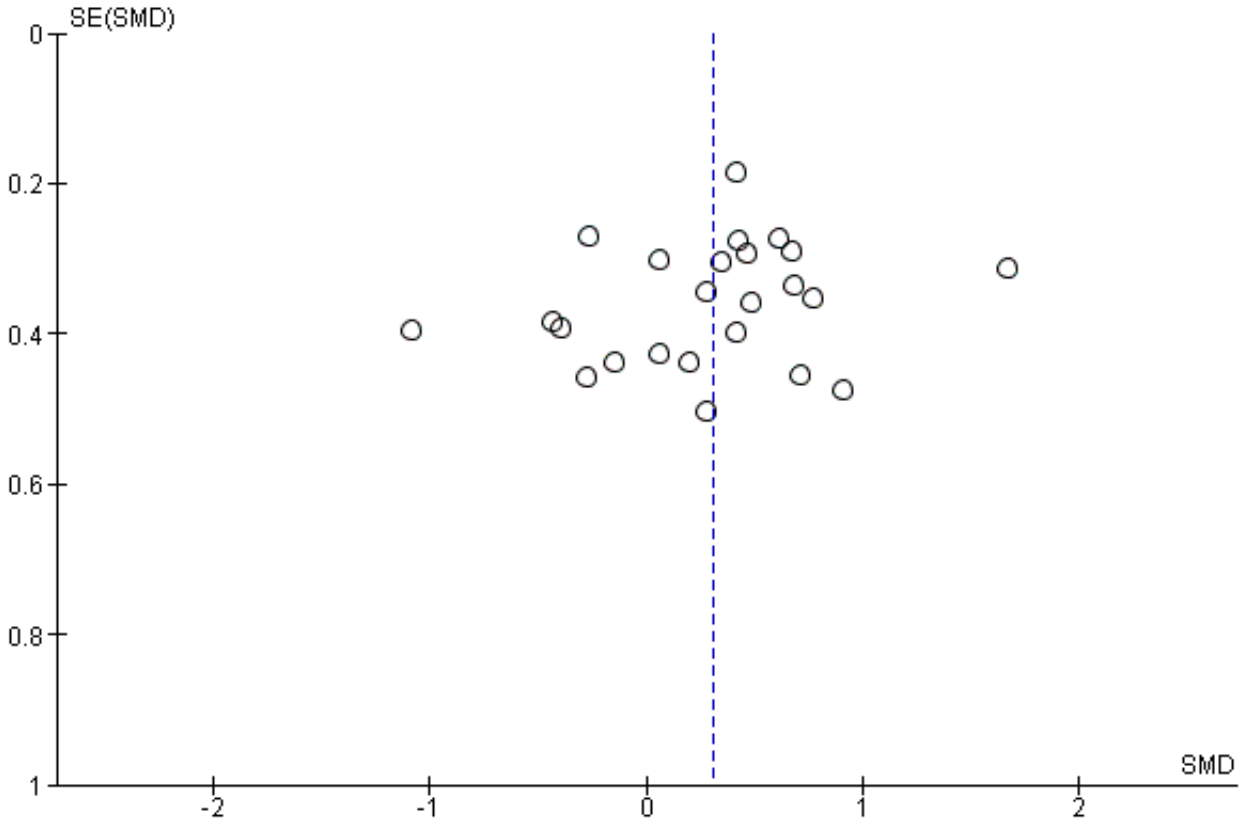
Electromechanical and robot-assisted arm training versus any other intervention

See Summary of findings for the main comparison.

Activities of daily living at the end of the intervention phase

Twenty-four studies with a total of 957 participants compared electromechanical and robot-assisted arm training versus any other intervention and measured activities of daily living. Electromechanical and robot-assisted arm training improved activities of daily living scores. The pooled SMD (random-effects model) for activities of daily living was 0.31 (95% CI 0.09 to 0.52, P = 0.005, level of heterogeneity I^2 = 59%; Analysis 1.1; high-quality evidence). We did not find graphical evidence in a funnel plot for publication bias (Figure 3).

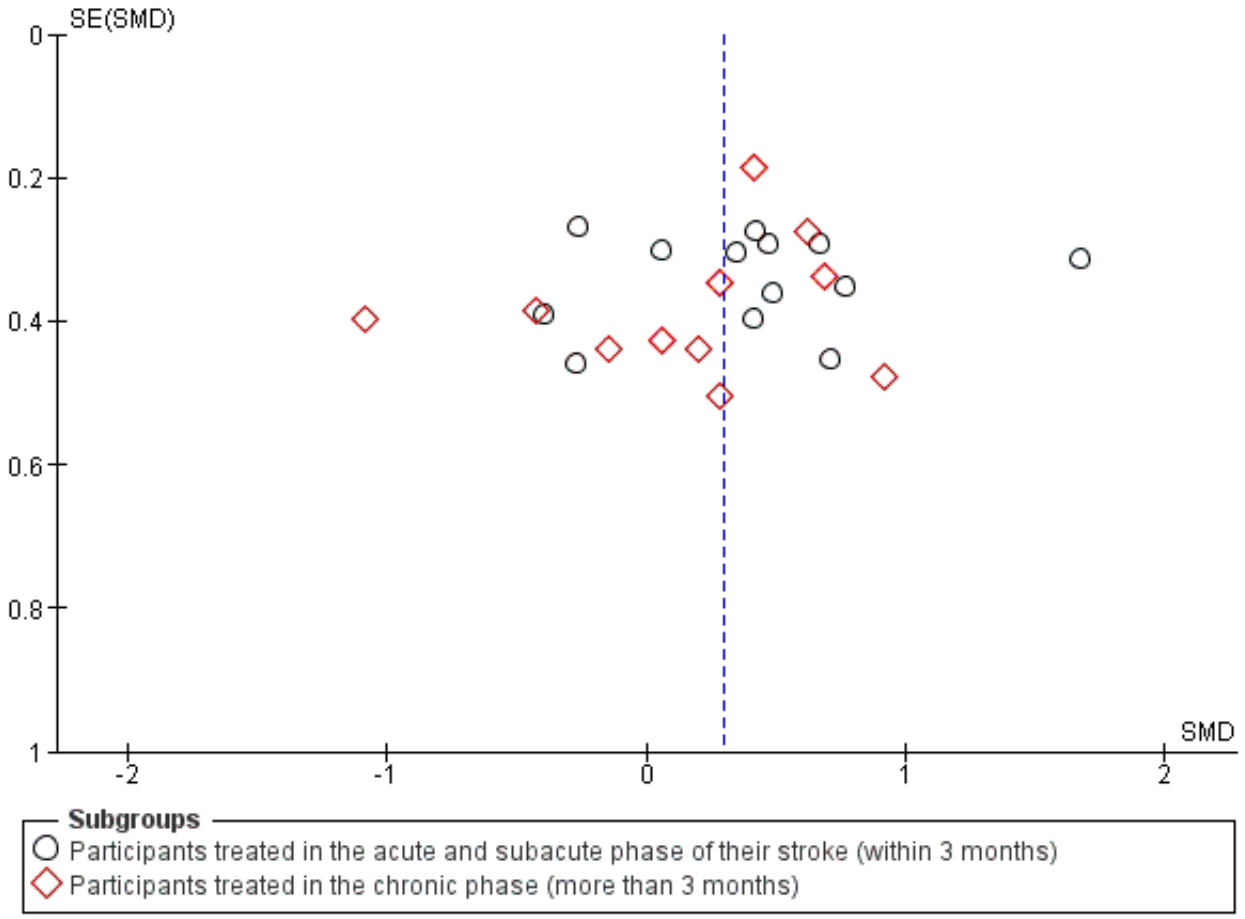
Figure 3. Funnel plot of comparison: 1 Electromechanical and robotic assisted training versus all other intervention, outcome: 1.1 Activities of daily living at the end of intervention phase.



Activities of daily living at the end of the intervention phase: subgroup analysis comparing the acute and chronic phase

We included 13 trials with a total of 532 participants in the acute and subacute phase after stroke. Electromechanical and robot-assisted arm training improved activities of daily living scores in the acute phase after stroke; the SMD (random-effects model) was 0.40 (95% CI 0.10 to 0.70, P = 0.009, level of heterogeneity I^2 = 63%). We included 11 trials with a total of 425 participants in the chronic phase (more than three months after stroke). Electromechanical and robot-assisted arm training did not improve activities of daily living scores in the chronic phase after stroke; the SMD (random-effects model) was 0.19 (95% CI -0.13 to 0.50, P = 0.24 , level of heterogeneity I^2 = 54%; Analysis 1.2; high-quality evidence). The test for subgroup differences (between acute and subacute phase after stroke versus chronic phase after stroke) revealed no significant difference (P = 0.33, level of heterogeneity I^2 = 0%). We did not find graphical evidence in a funnel plot for publication bias (Figure 4).

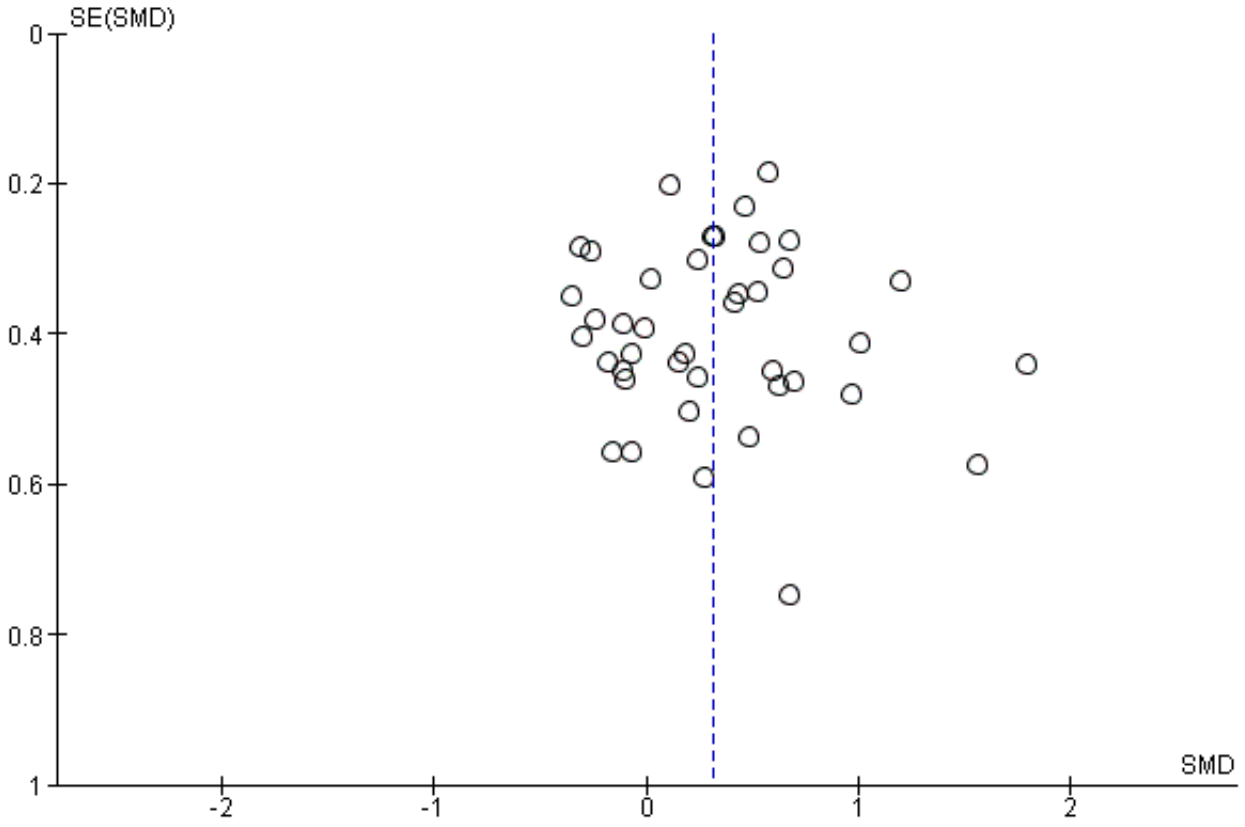
Figure 4. Funnel plot of comparison: 1 Electromechanical and robotic assisted training versus all other intervention, outcome: 1.2 Activities of daily living at the end of intervention phase: subgroup analysis comparing acute and chronic phase.



Arm function at the end of the intervention phase

Forty-one studies with a total of 1452 participants compared electromechanical and robot-assisted arm training versus any other intervention and measured arm function. Electromechanical and robot-assisted arm training improved arm function of the impaired arm. As we received the change data from baseline to study end for all trials that measured arm function, we used SMDs for this comparison. The pooled SMD (random-effects model) for arm function was 0.32 (95% CI 0.18 to 0.46, P < 0.0001, level of heterogeneity I^2 = 36%; Analysis 1.3; high-quality evidence). We did not find graphical evidence in a funnel plot for publication bias (Figure 5).

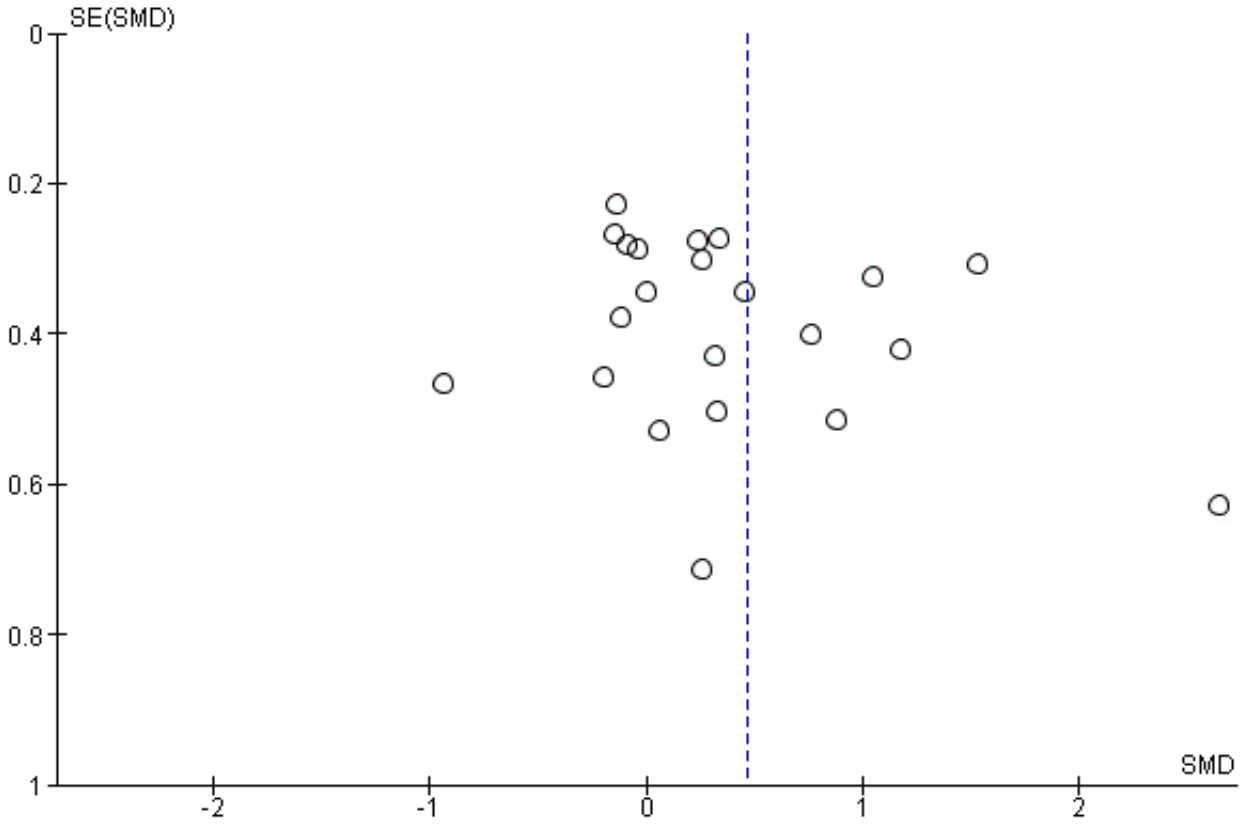
Figure 5. Funnel plot of comparison: 1 Electromechanical and robotic assisted training versus all other intervention, outcome: 1.3 Arm function at the end of intervention phase.



Arm muscle strength at the end of the intervention phase

Twenty-three studies with a total of 826 participants compared electromechanical and robot-assisted arm training versus another intervention and measured arm strength. Electromechanical and robot-assisted arm training improved arm muscle strength. The SMD (random-effects model) for muscle strength was 0.46 (95% CI 0.16 to 0.77, P = 0.003, level of heterogeneity I^2 = 76%; Analysis 1.4; high-quality evidence). We did not find graphical evidence in a funnel plot for publication bias (Figure 6).

Figure 6. Funnel plot of comparison: 1 Electromechanical and robotic assisted training versus all other intervention, outcome: 1.4 Arm muscle strength at the end of intervention phase.



Acceptability: dropouts during the intervention period

We pooled all reported rates of participants who dropped out from all causes during the trial period (45 studies with 1619 participants). The use of electromechanical and robot-assisted arm training in people after stroke did not increase the risk of participants dropping out. The RD (random-effects model) for dropouts was 0.00 (95% CI -0.02 to 0.02, P = 0.93, level of heterogeneity I^2 = 0%; Analysis 1.5; high-quality evidence).

The dropout rate for all reasons at the end of the treatment phase was relatively low (the dropout rate was less than 16%), but for one study this was still unclear (Amirabdollahian 2007). Twenty-six out of 45 included studies (59%) reported no dropouts at scheduled study end (Analysis 1.5). The highest dropout rate in the treatment group was 24% (seven dropouts out of 29 participants; Lee 2016). The highest dropout rate in the control group was also 24% (seven dropouts out of 29 participants; Lee 2016). Only one study in the early acute phase after stroke reported deaths during the treatment period (Masiero 2007). However, as explained by the authors via email correspondence, both deaths occurred in the control group. Other reasons for dropouts were:

- personal reasons (treatment group) (Daly 2005);
- personal reasons (control group) (Housman 2009);
- withdrew (treatment group) (Abdullah 2011; Klamroth-Marganska 2014);
- withdrew (control group) (Klamroth-Marganska 2014);
- injured arm in daily life (treatment group) (Housman 2009);
- depression (control group) (Housman 2009);
- refusing therapy (treatment group) (Hesse 2005; Klamroth-Marganska 2014);
- medical complications (treatment group) (Conroy 2011; Lum 2002);
- medical reasons (control group) (Klamroth-Marganska 2014);
- exclusion (control group) (Lum 2002);
- lost to follow-up (control group) (Susanto 2015);
- unable to travel (Lo 2010) or transportation difficulties (treatment group) (Kutner 2010);
- limited data (Conroy 2011; Hsieh 2014);
- moved (Conroy 2011; Housman 2009);
- did not met inclusion criteria after study commencement (Brokaw 2014).

Safety: adverse events during the intervention period

We did not carry out a pooled analysis because the reported rates of adverse events during the intervention period were rare and not related to the therapy (as described by the study authors). The reported adverse events were as described above: death in the control group, which was not related to the therapy (information as published by the study authors; Masiero 2007); and two participants experienced medical complications in the treatment group (information as published by the study authors; Lum 2002).

Sensitivity analysis: by trial methodology

Activities of daily living

To examine the robustness of the results, we specified variables in a sensitivity analysis that we believed could influence the size of effect observed (randomisation procedure, concealed allocation, and blinding of assessors) (Analysis 2.1). We did not investigate in this sensitivity analysis if selective reporting had an influence on the size of effect observed, because we did not find sufficient information to permit such a judgement.

All studies with description of randomisation procedure

We included 15 trials with a total of 661 participants with an adequate description of the randomisation procedure. Electromechanical and robot-assisted arm training improved activities of daily living. The SMD (random-effects model) for activities of daily living was 0.32 (95% CI 0.15 to 0.49, P = 0.0002, level of heterogeneity I^2 = 9%).

All studies with adequately concealed allocation

We included 10 trials with a total of 392 participants with adequate concealment of allocation. Electromechanical and robot-assisted arm training improved activities of daily living. The SMD (random-effects model) for activities of daily living was 0.28 (95% CI 0.03 to 0.52, P = 0.03, level of heterogeneity I^2 = 30%).

All studies with blinded outcome assessors

Twenty trials with a total of 808 participants had blinded assessors for the primary outcome. Electromechanical and robot-assisted arm training improved activities of daily living. The SMD (random-effects model) for activities of daily living was 0.29 (95% CI 0.10 to 0.49, P = 0.004, level of heterogeneity I^2 = 41%).

Arm function

To examine the robustness of the results, we specified variables in a sensitivity analysis that we believed could influence the size of effect observed (randomisation procedure, concealed allocation, and blinding of assessors) (Analysis 2.2).

All studies with description of randomisation procedure

We included 28 trials with a total of 1048 participants with an adequate description of the randomisation procedure. Electromechanical and robot-assisted arm training improved impaired arm function. The SMD (random-effects model) for arm function was 0.32 (95% CI 0.16 to 0.47, P < 0.0001, level of heterogeneity I^2 = 28%).

All studies with adequately concealed allocation

We included 12 trials with a total of 462 participants with adequate concealment of allocation. Electromechanical and robot-assisted arm training improved impaired arm function. The SMD (random-effects model) for arm function was 0.43 (95% CI 0.21 to 0.64, P = 0.0001, level of heterogeneity I^2 = 21%).

All studies with blinded assessors

We included 32 trials with a total of 1220 participants with blinded assessors. Electromechanical and robot-assisted arm training improved impaired arm function. The SMD (random-effects model) for arm function was 0.33 (95% CI 0.18 to 0.49, P < 0.0001, level of heterogeneity I^2 = 37%).

Subgroup analysis: by treatment approach

Activities of daily living at the end of intervention phase: subgroup analysis by treatment approach

The test for subgroup differences between a subgroup of participants who received mainly training for the distal arm and the hand (finger, hand, and radio-ulnar joints) and a subgroup of participants who received training mainly of the proximal arm (shoulder and elbow joints) revealed no significant difference (P = 0.64, level of heterogeneity I^2 = 0%; Analysis 3.1).

Arm function at the end of intervention phase: subgroup analysis by treatment approach

The test for subgroup differences between a subgroup of participants who received mainly training for the distal arm and the hand (finger, hand, and radio-ulnar joints) and a subgroup of participants who received training mainly of the proximal arm (shoulder and elbow joints) revealed no significant difference (P = 0.8, level of heterogeneity I^2 = 0%; Analysis 3.2).

DISCUSSION

Summary of main results

We included 45 trials (involving 1619 participants) in this update of our systematic review of the effects of electromechanical and robot-assisted therapy for improving activities of daily living, arm function, and arm muscle strength. We found that the use of electromechanical-assistive devices in rehabilitation settings slightly improve activities of daily living, arm function, and arm strength, and we rated the quality of evidence as high. Furthermore, adverse events and dropouts were uncommon and did not appear to be more frequent in those participants who received electromechanical and robot-assisted arm training, graded as high-quality evidence. This indicates that the use of electromechanical and robot-assisted arm training devices could be safe and acceptable to most participants included in the trials that this review analysed. It appears to be that electromechanical and robot-assisted arm training slightly improves important outcomes after stroke.

When looking at certain groups of participants, we found no significant difference in improvements of activities of daily living between subgroups based on phase after stroke. Participants who received mainly training for the distal arm and the hand (finger, hand, and radio-ulnar joints) and participants who received training mainly of the proximal arm (shoulder and elbow joints) did not differ significantly with regard to activities of daily living and arm function.

Electromechanical and robot-assisted therapy uses devices simply as 'vehicles' to apply an increased intensity in terms of many repetitions of arm training (Kwakkel 2008; Kwakkel 2015). It seems unlikely that motor therapy provided by robots will lead to better results than motor therapy provided by humans under the premise that intensity, amount, and frequency of therapy are exactly comparable. The potential advantage of electromechanical devices, when compared with conventional therapies, may be an increase in repetitions during arm training and an increase of motivation to train. Additionally, because people using electromechanical and robot-assistance therapy are able to practise without a therapist, this type of training has the potential

to increase the number of repetitions of practice. However, in our analysis of the included studies in this review update, we were not able to compare different amounts of repetitions of arm training. The number of repetitions and also the exact intensity, time, dose, amount, and frequency of applied therapies were not described in detail in most of the studies included here. However, almost all of the included studies (but not Yoo 2013) had an active control group, and most studies matched the time for therapy between in-treatment and control groups. One could, therefore, argue that robot-assisted arm therapy after stroke is more effective in improving activities of daily living, arm function, and arm strength than other interventions if the same time of practice is offered. Then again, as mentioned above, it could just be that more repetitions in the same time were applied by robotic-assisted arm training (higher dose). This appears to be an important issue that should be taken into account when discussing the effectiveness of electromechanical and robot-assisted therapy for improving activities of daily living, arm function, and arm muscle strength.

Overall completeness and applicability of evidence

The results of this review seem to be quite generalisable for settings in industrialised countries and especially for rehabilitation centres with available electromechanical and robot-assisted devices. However, the following factors produce uncertainty.

- Most of the studies included participants with first-ever stroke.
- The majority of participants suffered from ischaemic stroke.
- Nearly all of the participants were right-handed.
- The exclusion of certain patient groups, such as people with unstable cardiovascular conditions, cognitive and communication deficits, or with a limited range of motion in the arm joints at the start of the intervention (it is well known that limited range of motion is common after stroke).

Hence, the results may be of limited applicability for people with recurrent stroke or haemorrhagic stroke.

The relatively tight selection criteria that have been applied to many studies should be considered. For example, the relatively younger age of people who were studied should be recognised, and also many of the people studied had no limitations of passive range of motion or were free of shoulder pain. It is well known in clinical practice that many people with stroke are older and that the prevalence of comorbidities, such as pain, spasticity, or limitations to range of motion, is expected to be higher than described in the studies included here.

Additionally, electromechanical and robot-assisted training could create additional costs of rehabilitation after stroke. The general applicability of robot therapy might, therefore, be limited simply due to lack of access to devices, for example, in many low-income countries, and there also appears to be fewer opportunities for therapists and patients to access robots in outpatient than in inpatient settings. All these points taken together might limit the applicability of this type of therapy in day-to-day clinical routine.

Quality of the evidence

We found heterogeneity regarding trial design (parallel-group or cross-over design, two or three or more intervention groups), therapy variables (type of device, bilateral or unilateral assistance, proximal or distal assistance, dosage of therapy), and participant characteristics (age, time post-stroke, and severity of arm paresis).

There were enough studies to perform our planned sensitivity analysis examining the effects of methodological quality on the effectiveness of the intervention. We found that the effects of electromechanical-assistive devices for improving activities of daily living and for improving arm function were quite stable and not affected by methodological quality (Analysis 2.1; Analysis 2.2).

Compared to former updates of this review, we have rated the quality of evidence now as high. We found no serious limitations (in respect to study limitations, inconsistency, indirectness, imprecision, or publication bias) to downgrade the evidence and decided after discussion and consensus to grade the evidence for outcomes as high. Therefore, in this update of our review, we are confident that there are small benefits of robot therapy for improving activities of daily living, arm function, and arm muscle strength without evidence of side effects or harm; at the moment, we believe that further research is very unlikely to change our confidence in the estimate of effect for our outcomes.

Potential biases in the review process

The methodological rigour of Cochrane Reviews minimises bias in the process of conducting systematic reviews. A risk of publication bias, however, is present in all systematic reviews.

We searched extensively for relevant literature in electronic databases and handsearched conference abstracts. Additionally, we contacted authors, trialists, and experts in the field for other unpublished and ongoing trials. We were unable to find graphical evidence for publication bias using funnel plots. There was heterogeneity between the trials in terms of trial design (two groups, four groups, parallel-group or cross-over trial, duration of study and follow-up, and selection criteria for participants), characteristics of the therapy interventions (especially the device used), and participant characteristics (length of time since stroke onset). There were also methodological differences in the mechanism of randomisation and allocation concealment methods used and blinding of primary outcomes.

After examination of the influence of methodological quality on the observed effect on activities of daily living and arm function, we did not find a change of benefit when we removed trials with unclear randomisation or allocation concealment procedures or unclear blinding.

While the methodological quality of the included trials was in general good to very good, although heterogeneous (Figure 2), trials investigating electromechanical and robot-assisted arm training were subject to potential methodological limitations. These limitations include inability to blind the therapist and participants, contamination (provision of the intervention to the control group), and cointervention (when the same therapist unintentionally provides additional care to either treatment or comparison group). All these potential methodological limitations introduced the possibility of performance bias. However, as discussed above, our sensitivity analyses by methodological quality did not support this.

Some of the statistical analyses used in the review were based on parametric statistics. However, one could argue that it might not be appropriate to treat some scores for activities of daily

living (e.g. Barthel Index score ranging from 0 to 100) and arm function (e.g. Fugl-Meyer score ranging from 0 to 66) included in this review with this approach. Most of these scores were used in the included trials as continuous scales, and by others as ordinal scaled scores. However, it is unclear how this has led to an over- or underestimation of our described treatment effects.

Some could argue that other tests for upper limb function after stroke would be more sensitive to detection of changes in motor function targeted by the interventions studied here. However, we decided, in this update of our review, to keep on the predefined assessments as preplanned in our published protocol for this review.

One could argue that participation or reintegration in normal living was not assessed in this review. There is, however, until now, no consensus how to measure participation after stroke and most of the included studies were not designed for, and did not use, appropriate scales to measure participation for their primary outcome. For future updates of this review, however, we will consider investigating the effects on participation.

Some people would suggest not examining the effects of electromechanical and robot-assisted therapy with the FIM and Barthel, because they might be more relevant in the early stages of stroke recovery, and they emphasise that burden of care and many items in both batteries do not include upper extremity motor function. However, we decided in this update of our review to keep to the predefined assessments as preplanned in our published protocol for this review. It is unclear how this has led to an over- or underestimation of our described treatment effects.

As is always the case in systematic reviews, publication bias could have potentially affected our results. The visual inspection of funnel plots for our main outcomes did not show evidence of publication bias (Figure 3; Figure 5; Figure 6); however, this does not mean there was complete absence of publication bias. Publication bias could, therefore, potentially be an issue, but it is unclear if this has led to an serious overestimation of our described treatment effects.

Most of the included studies compared the same time and frequency of therapy in their study arms. However, that does not mean that study groups received the same intensity of therapy in terms of repetition per therapy session. The exact therapy intensity and also the exact description of therapy interventions was not well described in many of the included studies and did not adhere to the 'Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide' (Hoffmann 2014).

Agreements and disagreements with other studies or reviews

As far as we know, only one other systematic reviews of RCTs about electromechanical and robot-assisted therapy for improving activities of daily living, arm function, and arm muscle strength has been conducted in the last three years. The most recent systematic review of this topic was done in 2017 (Veerbeek 2017). This systematic review searched for the effects of robot-assisted therapy for the upper limb after stroke. The authors included in their meta-analyses 38 studies with a total of 1206 participants investigating robotic arm training to improve motor control. Veerbeek and colleagues found significant but small improvements in motor control (˜ 2 points of the FMA) and muscle strength of the paretic arm and a negative effect on muscle tone (Veerbeek 2017). In contrast to our review, the authors did not find significant effects on basic ADL. Additionally, in contrast to our review, Verbeek and colleagues found that shoulder/elbow robotics might have small but significant effects on motor control and muscle strength, while elbow/wrist robotics had small but significant effects on motor control. There are, however, several differences between our Cochrane review and the systematic reviews of Verbeek and colleagues. First, we used a peer-reviewed and prepublished protocol for our review (Mehrholz 2008), and kept strictly to the methodological recommendations of the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2017). Second, we used different inclusion criteria for potentially eligible studies (and therefore excluded some of those studies included in the review of Veerbeek 2017). Third, we used different outcome measures, according to our protocol for this review. These three divergences between the reviews could easily explain the different effects found.

Another up-to-date review also included trials using robotic training in combination with other interventions for people with stroke (Laver 2017). However, the authors specifically investigated the efficacy of virtual reality compared with an alternative intervention or no intervention on upper limb function and activity.

AUTHORS' CONCLUSIONS

Implications for practice

We found that people after stroke who receive electromechanical or robot-assisted arm training are more likely to show improvement in their activities of daily living, arm function, and muscle strength of the paretic arm, and we rated the quality of evidence as high.

In practice, electromechanical or robot-assisted arm training could increase the intensity of arm therapy. Perhaps more repetitions during the same therapy time can be achieved if electromechanical and robot-assisted therapy is given. Electromechanical devices could, therefore, be used as an adjunct to conventional therapies.

However, it is still not clear if the difference between electromechanical or robot-assisted arm training and other interventions is clinically meaningful for most people after stroke. Perhaps one main difference between electromechanical or robot-assisted arm training and other interventions could be an improvement in motivation due to the feedback of the device, or the novelty of a robotic device, or both. However, we can only speculate about this.

Implications for research

There is still a need for well-designed, large-scale, multicentre studies to evaluate benefits and harms of electromechanical-assisted arm training after stroke. Further research should count the number of repetitions in time and address specific questions about the type, timing, frequency, and duration of electromechanical and robot-assisted arm training. Further research should also investigate whether or not there is any benefit over and above the amount of practice, for example, if it would be useful or not if a robot prevents 'incorrect learning or movements'. Additionally, improved reporting of trial methods and the use of published reporting guidelines for trials are essential.

It may be useful if future studies could use arm function-specific outcome measures and measures of repetitions during training to gain a better understanding of the explicit effects of this special form of training.

Future studies should better report the interventions and should therefore adhere to the TiDIER guidelines when describing content, frequency and dose of therapy, and the personnel supervising participants during training.

Future studies should investigate the effects on participation and should also investigate the most severely affected people and groups, who are not reflected so far in the existing trials.

We found a dropout rate of often less than 5%. Future studies could determine their sample size calculations based on this dropout rate.

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

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

Abdullah 2011

Methods	RCT
Participants	Country: Canada Sample size: 20 participants (9 in treatment group, 11 in control group) Inclusion criteria: first single, unilateral stroke; informed consent; age between 16 and 90 years; 2 to 8 weeks after stroke; motor arm impairment between stages 1 and 4 measured by CMSA Exclusion criteria: shoulder pain between 1 and 3 as measured by CMSA pain inventory scale; presence of other condition in the affected shoulder or elbow
Interventions	2 groups: 1. robotic-mediated therapy for 45 minutes, 3 times a week for 8 to 11 weeks 2. conventional arm therapy for 45 minutes, 3 times a week for 8 to 11 weeks
Outcomes	Outcome measures were assessed at baseline and at the end of the intervention period Primary outcome measure: Chedoke Arm and Hand Activity Inventory (CAHAI-7) Secondary outcome measures: CMSA, client satisfaction using a 10-point Likert scale
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "A physiotherapist unrelated to the study randomized the participants into one of two groups using a random number table."
Allocation concealment (selection bias)	Unclear risk	Not described

Abdullah 2011 *(Continued)*

Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "An occupational therapist blinded to patient allocation administered the CAHAI-7 and the CMSA at admission and discharge."
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Amirabdollahian 2007

Methods	Cross-over RCT Method of randomisation: selecting a sealed envelope
Participants	Countries: UK and Republic of Ireland Sample size: 31 participants (16 in treatment group, 15 in control group) Inclusion criteria: medically stable; first stroke; over 60 years of age; able to give informed consent; a score higher than 24 in the Short Orientation-Memory-Concentration Test Exclusion criteria: people with pacemakers
Interventions	2 groups: 1. group ABC: 3 weeks baseline (Phase A) then 3 weeks robot-mediated therapy (Phase B) then 3 weeks sling suspension (Phase C) 2. group ACB: 3 weeks baseline (Phase A) then 3 weeks sling suspension (Phase C) then 3 weeks robot-mediated therapy (Phase B)
Outcomes	Outcomes were recorded before and after baseline, after 3 weeks of therapy and again 3 weeks later (after each cross-over) Fugl-Meyer scale (0 to 66)
Notes	We planned to use Phase B data for group 1 (experimental) and Phase C data for group 2 (control) in the analysis

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Random sequence generation not exactly stated
Allocation concealment (selection bias)	Unclear risk	Insufficient information about the sequence generation process
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Blinding procedure not exactly stated
Selective reporting (reporting bias)	High risk	One or more outcomes were reported incompletely

Ang 2014

Methods	RCT

Ang 2014 *(Continued)*

Participants	Country: Singapore Sample size: 21 participants (7 in treatment group: brain computer interface with haptic knob device (BCI-HK); 8 in treatment group: HK; 7 in control group) Inclusion criteria: first-ever stroke, confirmed by neuroimaging; age 21 to 80 years; time since stroke > 4 months; FMA-score 10 to 50 points (moderate to severe arm impairment); motor power grade 2 to 5 MRC shoulder abduction, grade 2 to 5 MRC elbow flexion, and grade 1 to 3 MRC in wrist dorsiflexion and finger flexion Exclusion criteria: medical instability; postural hypotension; terminal illness; severe aphasia; inattention; hemispatial neglect; severe visual impairment; epilepsy; severe depression; psychiatric disorders; recurrent stroke; skull defect; severe spasticity; fixed joint contractures; skin lesions
Interventions	3 groups: 1. robot-mediated therapy with the haptic knob robot and a brain computer interface for 60 minutes + therapist-assisted arm mobilisation for 30 minutes 2. robot-mediated therapy with the haptic knob robot alone for 60 minutes + therapist-assisted arm mobilisation for 30 minutes 3. standard arm therapy for 60 minutes + therapist-assisted arm mobilisation for 30 minutes
Outcomes	Outcomes were measured at baseline (week 0), at mid-intervention (week 3), at the end of the intervention period (week 6), 6 weeks' follow-up (week 12), and 18 weeks' follow-up (week 24) Primary outcome: total FMA score
Notes	We combined the results of both HK groups in 1 (collapsed) group and compared this collapsed group with the results of the standard arm therapy group

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "The randomization block size was 3 and the allocation sequence was 1:1:1 generated using software"
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "As subject blinding was not feasible, all outcome assessments for this study were performed by occupational therapist DXD who was blinded to allocation."
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Brokaw 2014

Methods	Randomised cross-over trial
Participants	Country: USA Sample size: 12 participants

Brokaw 2014 *(Continued)*

	Inclusion criteria: adult with ischaemic/haemorrhagic stroke at least 6 months before; persistent hemiparesis (score 1 to 2 on the National Institutes of Health Stroke Scale); voluntary wrist and finger extension; shoulder elevation Exclusion criteria: a score of less than 24 on the MMSE; hemispatial neglect; severe sensory loss; excessive pain in any joint of the affected hemisphere or upper extremity injury
Interventions	2 groups: 1. group AB: 12 hours of robotic training within a month (A) and 12 hours of conventional therapy within a month (B), separated by a month of wash-out period 2. group BA: 12 hours of conventional therapy within a month (B) and 12 hours of robotic training within a month (A), separated by a month of wash-out period
Outcomes	FMA ARAT BBT
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "Randomization was done using a random number generator function in Matlab (MathWorks Inc, Natick, MA) that generated a list of numbers (1-10) randomly ordered"
Allocation concealment (selection bias)	Unclear risk	Quote: "The first 5 listed subject numbers received conventional therapy first and the second set received robot therapy first."
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "The OT performing recruitment and clinical evaluations was not aware of the randomization order, so was blinded to group assignment."
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Burgar 2011

Methods	Prospective, single-blinded RCT Method of randomisation: stratified random number table
Participants	Country: USA Sample size: 54 participants (19 in the first treatment group, 17 in the second treatment group, and 18 in the control group) Inclusion criteria: primary diagnosis of stroke Exclusion criteria: people were excluded if they exhibited upper limb joint pain that restricted normal movement, had absent proprioception at the elbow or shoulder joints, or scored less than 22 on the MMSE. People with cardiovascular, orthopaedic, or neurological conditions that would have precluded exercise in short-duration, moderate-workload trials were also excluded
Interventions	3 groups:

Burgar 2011 *(Continued)*

	1. Robot-Lo: received up to 15 1-hour therapy sessions over a 3-week period with the MIME system 2. Robot-Hi: received up to 30 1-hour therapy sessions over a 3-week period with the MIME system 3. control group: received up to 15 1-hour therapy sessions over a 3-week period
Outcomes	Outcomes were recorded at baseline, just after completion of training (after 3 weeks), and 6 months later (follow-up) 1. FMA (maximum 66 points) 2. FIM (upper limb, maximum 63 points) 3. Motor Power (maximum 70*) 4. Ashworth (MAS maximum 5 points) 5. WMFT Functional Ability Scale (maximum 5 and time in seconds) *The strength of 14 shoulder and elbow muscle groups was assessed by performing manual muscle testing of isolated joint actions and applying the MRC Motor Power grading scale (0 to 5) with a maximum possible score of 70 (scapular abduction/upward rotation, scapular elevation, adduction, adduction/depression, adduction/downward rotation, flexion, extension, abduction, horizontal adduction, horizontal abduction, external rotation, internal rotation, elbow flexion, elbow extension)
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Random number table
Allocation concealment (selection bias)	Unclear risk	Unclear, not reported
Blinding of outcome assessment (detection bias) All outcomes	Low risk	A second therapist at each site, blinded to group assignment, performed a clinical assessment battery just before study initiation, just after completion of training, and again at the 6-month follow-up
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Bustamante 2016

Methods	RCT
Participants	Country: Mexico Sample size: 27 participants (13 in treatment group; 14 in control group; 10/10 analysed) Inclusion criteria: 1) between 21 and 75 years; 2) hemiparesis due to a cerebral vascular accident stroke (confirmed by a physician); 3) at least 6 months post-stroke and medically stable; 4) ability to sit for 60 minutes and to stand, assisted or unassisted, for 30–40 minutes; 5) a score less than 8 on the Geriatric Depression Scale indicating mild depression and a likelihood of completing the 24 sessions required; 6) not be more than moderately cognitively impaired as defined by a MMSE score greater than 20 – participants were able to give consent and understand instructions; 7) residual movement in shoulder flexion/adduction and active elbow flexion/extension and/or residual movement in leg flexion/extension and hip adduction as defined by a Brunnstrom Test Score ranging from 2 to 5; and 8) had a muscle strength scores on the Manual Muscle Test between > 1 and < 3 in both extremities Exclusion criteria: 1) excessive spasticity in upper and lower limbs as measured by the Ashworth scale over 4; 2) pain exceeding 4 on a visual analogue pain scale; 3) total paralysis or muscular contractures

Bustamante 2016 *(Continued)*

	of upper or lower extremity; 4) a history of psychiatric disorder or cardiac problems; 5) metallic implants near electrical stimulation site or cardiac defibrillators implants; 6) were pregnant or breast feeding; and 7) were unwilling to participate or comply with the protocol
Interventions	2 groups: 1. robot therapy with the Robot Gym therapy (RT) consisting of 6 stations of computer and motor assisted devices to aid in the motor rehabilitation of the upper and lower extremities, switched stations in the Robot Gym every half hour, working on 4 stations per day throughout the 24 sessions (Station A - TheraDrive: a low-cost system for personalised arm rehabilitation based on the theradrive robot; Station - NESS H200: a commercial hand rehabilitation system that provides FES to help open and close a patient's hand while performing functional daily activities as grab, pile and move different objects; Station C - NESS L300: a commercial foot-drop system using FES to assist dorsiflexion to help improve the patient's gait; Station D and E - MOTOmed viva 2 lower and MOTOmed viva 2 upper extremity: a motor-assisted device that allows passive or active resistance training through a series of simple games for movement therapy; Station F - Captains Log Brain Trainer: this commercial cognitive rehabilitation therapy system provides systematic brain training to patients with brain injury and aims to improve neuroplasticity) 2. control group received standard rehabilitation therapy, which included personalised physical and occupational therapy usually in a one-on-one therapist to patient ratio. Standard rehabilitation therapy included manual mobilisations, heat, ultrasound, therapeutic TENs, and repetitive tasks for occupational therapy using tools such as balls, cone sets, exercise bands, among others. All of the participants repeated the clinical evaluations post-therapy All study participants were subjected to 24 2-hour therapy sessions over a period of 6 to 8 weeks
Outcomes	Outcomes were measured at baseline (week 0) and at the end of intervention period (week 6 to 8) Primary outcome: total FMA score, the Rancho Los Amigos Functional Test for the upper extremity, and the Box and Block Test
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Authors stated: "An allocation sequence was generated using the Epidat 4.0 software to randomly assign numbers from 1 to 30 into two groups"
Allocation concealment (selection bias)	Unclear risk	Insufficient information to permit judgement of 'low' or 'high' risk
Blinding of outcome assessment (detection bias) All outcomes	High risk	No blinding of outcome assessment
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement; 7 of 27 participants initially included in the study were not described in results section

Conroy 2011

Methods	Prospective, single-blinded RCT Method of randomisation: choosing a sealed envelope
Participants	Country: USA Sample size: 62 participants (41 in the treatment group and 21 in the control group)

Conroy 2011 *(Continued)*

	Inclusion criteria: diagnosis of clinically defined, unilateral hemiparetic stroke with radiologic exclusion of other possible diagnoses; onset of stroke 6 months before randomisation for ischaemic stroke, 12 months for haemorrhagic stroke; manual muscle testing of grade 3 or lower for at least 1 muscle of the affected arm; > 18 years of age Exclusion criteria: serious complicating medical illness or stroke occurring within the previous 6 months (or both); contractures or orthopaedic problems limiting the range of joint movement in the potential study arm; visual loss limiting the ability to see the test patterns on the robot monitor; Botox injection of the affected arm 3 months before study onset or during the study
Interventions	3 groups: 1. group A: received robot-assisted planar reaching tasks with the InMotion 2.0 shoulder/arm over 6 weeks, 3 sessions per week for 1 hour 2. group B: received robot-assisted planar and vertical reaching tasks with the InMotion Linear Robot over the same time and frequency 3. group C: participants received intensive conventional arm exercise, which includes, for example, 40 minutes of repetitive arm motion using an arm ergometer, or task specific and functional reaching tasks (cones), in addition to 10 minutes of passive and guided stretching and 10 minutes of repositioning and rest between activities
Outcomes	Outcomes were recorded 3 times at baseline and after 6 weeks and 3 months later (follow-up) 1. FMA 2. WMFT 3. SIS
Notes	We combined the results of both the planar group and the planar and vertical group in 1 (collapsed) group and compared this collapsed group with the results of the control group

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Stratified randomisation by a computer scheme
Allocation concealment (selection bias)	Unclear risk	Insufficient information about the sequence generation process
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Assessment was performed by a single experienced evaluator blinded to group assignment
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Daly 2005

Methods	RCT Method of randomisation: drawing of tickets from envelopes by a person not involved in or aware of the allocation process
Participants	Country: USA Sample size: 13 participants (7 in treatment group, 6 in control group) Inclusion criteria: > 12 months after stroke, at least grade 1 muscle contraction in wrist extensors, and a score of > 10 on the Fugl-Meyer upper-limb score (0 to 66)

Daly 2005 *(Continued)*

	Exclusion criteria: not stated
Interventions	2 groups: 1. control group trained arms with functional neuromuscular stimulation 5 hours a day, 5 days a week for 12 weeks 2. experimental group (robotics and motor learning) had the same amount and frequency of treatment, but during 1.5 hours of the daily treatment session, participants used the InMotion robot for practising shoulder/elbow movements
Outcomes	Outcomes were recorded at baseline and after 4 weeks and 3 months later 1. AMAT 2. FMA (0 to 66) 3. the motor control measures of target accuracy, smoothness of movement
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	The investigators describe a stratified randomisation, but there was insufficient information about the sequence generation process
Allocation concealment (selection bias)	Unclear risk	Insufficient information about the sequence generation process
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Author stated that a blinded examiner scored the primary outcome measure from a videotape
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Fazekas 2007

Methods	RCT Method of randomisation: by a person not involved in the study
Participants	Country: Hungary Sample size: 30 participants (15 in treatment group, 15 in control group; 22 after stroke and 8 after traumatic brain injury) Inclusion criteria: hemiparesis after stroke or traumatic brain injury Exclusion criteria: not stated
Interventions	2 arms: 1. control group received 30 minutes of Bobath therapy sessions on 20 consecutive workdays 2. treatment group received same therapy as control group, but an additional 30 minutes of robot therapy
Outcomes	Outcomes were recorded at baseline and after the 10th session and at the end of the training 1. MAS of shoulder adductors and elbow flexors 2. range of motion of shoulder and elbow

Fazekas 2007 *(Continued)*

3. FMA (shoulder and elbow subsection; 0 to 36)
4. Rivermead Motor Assessment, arm score
5. FIM, self care subsection

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Insufficient information about the sequence generation process
Allocation concealment (selection bias)	Unclear risk	Insufficient information about the concealment of allocation
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Author stated that assessment was performed by a blinded physiotherapist
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Grigoras 2016

Methods	RCT
Participants	Country: Romania Sample size: 25 participants (13 in treatment group; 12 in control group) Inclusion criteria: patients with left hemiparesis, patients with a single ischaemic or haemorrhagic stroke on CT or MRI, patients between 1 month and 6 months post-stroke (subacute), patients with a FMA between 15 and 50, patients that signed the informed consent approved by the Rehabilitation Hospital Ethics Committee Exclusion criteria: patients with severe comorbidities; patients with other neurological, muscular or orthopaedic disorders; patients with apraxic, perceptual or cognitive deficit (MMSE below 25)
Interventions	2 groups: 1. robot therapy with the hybrid FES-exoskeleton system for hand rehabilitation for 12 sessions of 30 minutes 2. standard arm therapy for 10 sessions of 30 minutes The control group underwent standard conventional therapy and the experimental group underwent conventional therapy and robotic therapy
Outcomes	Outcomes were measured at baseline (week 0), at the end of intervention period (week 2) Primary outcome: total FMA score, BBT, SIS
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement

Grigoras 2016 *(Continued)*

Random sequence generation (selection bias)	Unclear risk	Authors stated 'randomly assigned' but not how this was done
Allocation concealment (selection bias)	Unclear risk	Insufficient information to permit judgement of 'low' or 'high' risk
Blinding of outcome assessment (detection bias) All outcomes	High risk	No blinding was done
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement of 'low' or 'high' risk

Hesse 2005

Methods	RCT Method of randomisation: participant drew a lot out of the sealed envelope presented by an independent person
Participants	Country: Germany Sample size: 44 participants (22 in treatment group, 22 in control group) Inclusion criteria: first-time supratentorial stroke; stroke interval before study onset 4 to 8 weeks; severe arm paresis with no or only a palpable volitional activity of the wrist and finger extensors (i.e. MRC 0 or 1); an initial Fugl-Meyer arm motor score (0 to 66) of less then 18; absent or moderate elbow, wrist, and finger spasticity; able to understand the meaning of the study; and written informed consent to participate in the approved study Exclusion criteria: apraxia (i.e. 1 fault in the tasks waving goodbye, saluting, and making a fist with the non-affected hand after verbal instruction and demonstration, and using an eraser, comb, and screwdriver with the objects handed to the person and verbally instructed); shoulder pain insensitive to standard therapy; hand swelling sufficient to prevent fist formation; painful arthritis of the wrist or finger joints; and forearm skin ulcers
Interventions	2 groups: 1. control group received, in addition to their standard inpatient rehabilitation programme 5 times a week for 6 weeks (if possible EMG-initiated), functional electrical stimulation for wrist extension 2. experimental group received, in addition to their standard inpatient rehabilitation programme for the same time and frequency as the control group, therapy with the Bi-Manu-Track robotic arm trainer
Outcomes	Outcomes were recorded at baseline and after 6 weeks and 3 months later 1. FMA (0 to 66) 2. MRC score (0 to 5) muscle strength of the shoulder abductors, flexors, and extensors of the elbow, the wrist, the fingers, and the thumb. A total MRC sum score (0 to 45) included a proximal MRC subscore (0 to 15) and a MRC distal subscore (0 to 30) 3. MAS (0 to 5) assessed the tone of the shoulder adductors, the flexors of the elbow, wrist, fingers, and the thumb. A total MAS score (0 to 25), a proximal MAS score (0 to 10), and a distal MAS score (0 to 15) were calculated
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement

Hesse 2005 *(Continued)*

Random sequence generation (selection bias)	Low risk	Sequence generation was done by shuffling envelopes
Allocation concealment (selection bias)	Low risk	Using sealed envelopes
Blinding of outcome assessment (detection bias) All outcomes	Low risk	A blinded therapist rated the videos of all participants
Selective reporting (reporting bias)	Low risk	Study protocol was available and all of the study's prespecified (primary and secondary) outcomes that were of interest in the review were reported in the prespecified way

Hesse 2014

Methods	RCT
Participants	Country: Germany Sample size: 50 (25 in the experimental group and 25 in the control group) Inclusion criteria: first-time supratentorial stroke; time since stroke more than 8 weeks; aged between 18 and 90 years; being able to get out of bed and mobilised in a wheelchair or being able to walk; Fugl-Meyer score < 35 Exlusion criteria: severe arm spasticity; hemiparetic shoulder pain; swollen hand impeding closing the fist
Interventions	2 groups: 1. robot-assisted group therapy for 30 minutes + individual arm therapy for 30 minutes, each workday for 4 weeks 2. individual arm therapy for 2 x 30 minutes each workday for 4 weeks
Outcomes	Outcomes were recorded at baseline, after 4 weeks at the end of intervention period, and at 3 months' follow-up Primary outcome: FMA Secondary outcomes: ARAT, BBT, MRC (upper limb muscles), MAS (upper limbs), Barthel Index
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "The allocation of patients to the two groups (robot-assisted group therapy or individual arm therapy) was conducted online by using a web-based randomization tool (www.randomizer.at)."
Allocation concealment (selection bias)	Low risk	Quote: "The allocation of patients to the two groups (robot-assisted group therapy or individual arm therapy) was conducted online by using a web-based randomization tool (www.randomizer.at)."

Hesse 2014 *(Continued)*

Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "The test was videographed with a mirror placed behind the patient to ensure later blind rating by an external experienced therapist."
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Hollenstein 2011

Methods	Cross-over RCT A cross-over design was used (only the first period before cross-over was used for data analysis) Methods of randomisation: described as follows: "subjects were randomly assigned by lottery of the supervising therapist"
Participants	Country: Germany Sample size: 13 participants (7 in treatment group, 6 in control group) Inclusion criteria: first-time stroke, affected arm and first rehabilitation Exclusion criteria: none described
Interventions	2 groups: 1. group A: received robot-mediated therapy with the Armeo device 5 times a week for 30 minutes over 2 weeks (10 times) 2. group B: received an arm group programme (without device) delivered by an occupational therapist for the same time and frequency as group A
Outcomes	Outcomes were recorded before and after 10 treatment sessions 1. FMA
Notes	This study was published in German

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Randomly assigned by lottery of the supervising therapist
Allocation concealment (selection bias)	Unclear risk	Insufficient information about the concealment of allocation
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Insufficient information about blinding
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Housman 2009

Methods	RCT

Housman 2009 *(Continued)*

	Methods of randomisation: participants were randomly assigned by a supervising therapist
Participants	Country: USA Sample size: 34 participants (17 in treatment group, 17 in control group) Inclusion criteria: single ischaemic or haemorrhagic stroke at least 6 months prior to participation, moderate to severe upper extremity hemiparesis (characterised by arm motor Fugl-Meyer scores > 10 and < 30) Exclusion criteria: significant pain or shoulder instability, current enrolment in ongoing upper extremity therapy, severe cognitive dysfunction, aphasia, hemispatial neglect, or apraxia
Interventions	2 groups: 1. group A: received robot-mediated therapy with the T-WREX device 3 times a week for 1 hour over 8 to 9 weeks, over the first 3 sessions the participants received direct training with an occupational therapist, and after that the participants exercised with intermittent supervision 2. group B: received the same treatment programme for the same time and frequency but without the device
Outcomes	Outcomes were recorded before and after every treatment session and 6 months after treatment completion FMA 1. Rancho Functional Test (functional use of the affected arm during activities of daily living) 2. MAL to evaluate the quality of movement and the amount of use of the affected arm during activities of daily living, used as a self report measurement 3. handheld dynamometer
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomly assigned by lottery of the supervising therapist
Allocation concealment (selection bias)	Low risk	The treating therapist and participants were blinded to assignment until each participant had consented and was enrolled in the project
Blinding of outcome assessment (detection bias) All outcomes	Low risk	A single-blinded rater performed the clinical assessments
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Hsieh 2011

Methods	Pilot RCT Methods of randomisation: by using a random-number table, a sealed envelope was given to the therapists after a new eligible participant was registered, to deliver therapy accordingly
Participants	Country: Taiwan

Hsieh 2011 *(Continued)*

	Sample size: 18 participants (6 in higher-intensity robot-assisted group, 6 in lower-intensity robot-assisted group, 6 in conventional rehabilitation group) Inclusion criteria: unilateral stroke onset at least 6 months prior to study; an initial upper extremity subsection of the Fugl-Meyer Assessment score of 30 to 56, indicating moderate to mild motor impairment; no excessive spasticity in elbow and wrist finger joints of the affected upper extremity (MAS < 3); ability to follow study instructions and perform study tasks (MMSE > 24); no upper limb fracture within 3 months; no participation in any experimental rehabilitation or drug studies during the study period; and written informed consent Exclusion criteria: painful arthritis of the elbow, wrist, or finger joints; severe neuropsychologic impairments; physician-determined major medical problems or poor physical condition that would interfere with participation; and cerebellar or brain stem lesions to limit potential interference of other symptoms or signs with task accomplishment
Interventions	3 groups: 1. higher-intensity RT group: Bi-Manu-Track used in this study for 20 training sessions for 90 to 105 minutes, 5 days per week for 4 weeks, within this group each participant practiced 600 to 800 repetitions of mode 1 (15 minutes), 600 to 800 repetitions of mode 2 (15 to 20 minutes), and 150 to 200 repetitions of mode 3 (5 minutes) for the forearm and wrist movement; after the RT, participants received 15 to 20 minutes of functional activities training to help them transfer the acquired motor ability into ADL 2. lower-intensity RT group: with the Bi-Manu-Track the participants received over the same time a different frequency of 300 to 400 repetitions of mode 1 (15 minutes), 300 to 400 repetitions of mode 2 (15 to 20 minutes), and 70 to 100 repetitions of mode 3 (5 minutes) for the forearm and wrist movement, and after that they received the same treatment of functional abilities as the higher-intensity group 3. conventional rehabilitation group: these participants received a structured protocol using conventional occupational therapy techniques including passive range-of-motion exercises for 15 to 20 minutes, fine-motor dexterity training for 20 minutes, gross-motor training for 20 minutes, muscle strengthening of the affected upper limb for 15 to 20 minutes, activities of daily living for 15 to 20 minutes
Outcomes	Outcomes were recorded at baseline and post-treatment 1. FMA 2. MRC 3. MAL 4. ABILHAND scale to measure bimanual ability
Notes	We combined the results of both the planar and the planar + vertical in 1 (collapsed) group and compared this collapsed group with the results of the control group

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	By random number table
Allocation concealment (selection bias)	Low risk	Sealed envelopes to accordingly deliver the intervention to the registered participant
Blinding of outcome assessment (detection bias) All outcomes	Low risk	All clinical measures were administered to the participants by the same blinded rater
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Hsieh 2014

Methods	RCT Methods of randomisation: random number table
Participants	Country: Taiwan Sample size: 48 Inclusion criteria: at least 6 months after onset of a unilateral stroke, an initial score of the FMA arm assessment of 20 to 50 (SD 25), minimal hand function (i.e. extension of the wrist ≥ 10°, extension of at least 2 fingers > 0° and > 10°, and abduction of thumb ≥ 10°, no excessive spasticity in any of the joints of the affected arm (MAS ≥ 4), no arm fracture within 3 months or painful arthritis of the joints, and able to follow study instructions and perform study tasks (MMSE ≥ 22) Exlusion criteria: none described
Interventions	3 groups: 1. RT + CIT group (robot-assisted arm therapy (Bi-Manu-Track) + constraint-induced therapy) 2. RT group (robot-assisted arm therapy (Bi-Manu-Track)) 3. CT group (received a therapist-mediated intervention using conventional occupational therapy techniques, including neurodevelopmental techniques, functional task practice, fine motor training, arm exercises or gross motor training, and muscle strengthening) Participants in each group received 20 training sessions of 90 to 105 min/day, 5 days/week for 4 weeks. In addition to the intervention provided in the clinics, all participants were encouraged to use their affected upper limb during activities in their daily life situations (e.g. at home)
Outcomes	Outcomes were recorded at baseline and post-treatment after 4 weeks 1. FMA 2. WMFT 3. MAL 4. accelerometers (actigraphy activity monitor)
Notes	We combined the results of both the RT + CIT group and the RT group (collapsed) group and compared this collapsed group with the results of the CT group

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomisation assignments were generated from a random number table
Allocation concealment (selection bias)	Low risk	Sequentially numbered, sealed, and opaque envelopes and a blinded investigator assigned each participant to a treatment group
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Blinded assessor
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Hwang 2012

Methods	RCT Methods of randomisation: random allocation of participants to 2 groups was performed using a random assignments generator (Wichmann–Hill random-number generator)
Participants	Country: Republic of Korea Sample size: 15 Inclusion criteria: ≥ 18 years old, more than 3 months after stroke, > 10° voluntary range of motion of the second metacarpophalangeal joint, a FMA arm motor scale of 2 to 20 for the wrist and hand subportion and requiring a > 25% longer time to finish the 9-hole pegboard test with the affected arm compared with the contralateral arm. Exlusion criteria: apraxia (≤ 2 on the Alexander scale), impaired consciousness (≥ 1 for the NIH Stroke Scale question Ia–c), sensory impairment (< 75% of the contralateral score on the Nottingham Sensory Scale), increased spasticity (4 on the Ashworth scale), aphasia (≥ 2 for the NIH Stroke Scale question IX) or depression (≥ 8 on the Geriatric Depression Scale), with a combined disabling disease on the hemiparetic hand, or who refused to participate
Interventions	2 groups: 1. 4 weeks (20 sessions) of active robot-assisted intervention (full-term intervention) group 2. 2 weeks (10 sessions) of early passive therapy, followed by 2 weeks (10 sessions) of active robot-assisted intervention (the half-term intervention) group The robot-assisted therapy included individual finger synchronisation (Amadeo, Tyromotion, Austria)
Outcomes	Outcomes were recorded at baseline and at 2, 4, and 8 weeks after starting therapy 1. FMA 2. Jebsen-Taylor test 3. MAS 4. 9-hole pegboard test 5. hand motor subscale of the SIS (involving 12 questions regarding hand function while activities of daily living, with a minimum score of 12 and maximum score of 60) 6. grasping force test 7. pinching force test 8. second metacarpophalangeal joint active range of motion
Notes	We used the data from the first 2 weeks of intervention

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Random allocation of participants into 2 groups was performed using a random assignments generator (Wichmann–Hill random-number generator)
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Authors quote: "assessor-blinded"

Hwang 2012 *(Continued)*

Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Kahn 2006

Methods	RCT Method of randomisation: not stated
Participants	Country: USA Sample size: 19 participants (10 in treatment group, 9 in control group) Inclusion criteria: unilateral stroke at least 1 year previously, CMSA 3 to 5 points scale Exclusion criteria: not stated
Interventions	2 groups: 1. control group received "free reaching training" that involved unconstrained, unassisted repetitive voluntary reaching in an 8-week therapy programme involving a total of 24 exercise sessions. Each session lasted 45 minutes 2. treatment group used robot-guided active-assist training with the ARM-Guide for the same time and frequency
Outcomes	Outcomes were recorded at baseline and after end of training 1. biomechanical examination of the impaired limb with the ARM Guide 2. CMSA 3. FMA 4. Rancho Los Amigos Functional Test for the hemiparetic upper extremity
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Insufficient information about the sequence generation process
Allocation concealment (selection bias)	Unclear risk	Insufficient information about the concealment of allocation
Blinding of outcome assessment (detection bias) All outcomes	Low risk	By a blinded evaluator
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Klamroth-Marganska 2014

Methods	RCT

Klamroth-Marganska 2014 *(Continued)*

	Methods of randomisation: computer-generated list of random numbers was used that paired a unique sequential number with a treatment type (robotic or conventional). Pairs were sealed in tamper-evident envelopes by the study coordinator
Participants	Country: Switzerland Sample size: 77 Inclusion criteria: diagnosis of 1, first-ever cerebrovascular accident verified by brain imaging (magnetic resonance imaging or computed tomography); chronic impairment after stroke (minimum 6 months); moderate to severe arm paresis as indicated by a score of 8 to 38 on arm section of FMA (which has a maximum of 66 points); aged ≥ 18 years; stable recovery stage; able to sit in a chair without any additional support and without leaning on the back rest; passive range of motion in the shoulder as assessed with the neutral zero method: anteversion/retroversion 80°/0°/20°, abduction/adduction 60°/0°/10°, inner and outer rotation 20°/0°/20°; passive range of motion in the elbow as assessed with the neutral zero method: flexion/extension 100°/40°/40° Exlusion criteria: excessive spasticity of the affected arm (MAS ≤ 3); serious medical or psychiatric disorder as assessed by their physician; participation in any clinical investigation within previous 4 weeks; participation in any therapeutic treatment (apart from assigned therapy) done with the paretic arm during the therapy phase of the study; anticipated need for any major surgery during the study; pregnancy or breastfeeding; orthopaedic, rheumatological, or other disease restricting movements of therapeutic arm; shoulder subluxation (palpation < 2 fingers); skin ulcerations at the paretic arm; not able to communicate effectively with the examiner such that the validity of the participant's data could be compromised; cyber sickness (e.g. nausea when looking at a screen or playing computer games); pacemaker or other implanted electric devices; bodyweight above 120 kg; serious cognitive defects or aphasia preventing effective use of ARMin
Interventions	2 groups: 1. robotic therapy with ARMin, each of 3 therapy modes (mobilisation, games, and training for activities of daily living) had to be done for at least 10 minutes 2. conventional therapy: receiving common neurorehabilitation treatment given to participants after stroke in outpatient facilities, namely occupational therapy or physiotherapy. Therapists were asked to give regular therapy, usually including mobilisation, games, activities of daily living, or any combination of the 3 Therapy was given 3 times a week for a period of 8 weeks (sum of 24 sessions). Minimum session time (excluding time for preparation, diagnostics, and documentation) was 45 minutes
Outcomes	Outcomes were recorded at baseline and post-treatment every 2 weeks 1. FMA 2. WMFT 3. quality of movement section of the MAL 4. Stroke Impact Scale (SIS 2.0) 5. Goal Attainment Scale 6. MAS 7. grip strength (handheld dynamometer)
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "computer-generated list of random numbers was used, which paired a unique sequential number with a treatment type (robotic or conventional)"

Klamroth-Marganska 2014 *(Continued)*

Allocation concealment (selection bias)	Low risk	Quote: "Pairs were sealed in tamper-evident envelopes by the study co-ordinator."
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "Assessors were masked to treatment allocation"
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Kutner 2010

Methods	RCT Methods of randomisation: sealed envelope method
Participants	Country: USA Sample size: 21 participants (11 in experimental group and 10 in combined therapy group) Inclusion criteria: first clinical stroke diagnosis; time since stroke between 3 and 9 months; MMSE score of > 24; being able to stand for 2 minutes; passive range of motion ≥ 45° for shoulder abduction, flexion, or external rotation and pronation of the forearm; active wrist extension ≥ 10°; active thumb extension and ≥ 10° of extension in at least 2 additional digits Exlusion criteria: not described
Interventions	2 groups: 1. 60 hours of repetitive task training over the course of 3 weeks 2. 30 hours of repetitive task training plus 30 hours of robotic-assisted training with the Hand Mentor device over the course of 3 weeks
Outcomes	Outcomes were recorded at baseline, at the end of intervention, and at 2 months postintervention Primary outcome measure: health-related quality of life (SIS)
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Quote: "participants were randomly assigned by the sealed envelope method"
Allocation concealment (selection bias)	Unclear risk	It was not described whether the sealed envelopes were opaque
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "Research staff blinded to treatment assignment conducted interview-based outcome assessments."
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Lee 2016

Methods	RCT
Participants	Country: Korea Sample size: 58 participants (29 in treatment group; 29 in control group) Inclusion criteria: subacute stroke patients with upper extremity spasticity of ≥ 1 point on the MAS, who were admitted to Department of Rehabilitation Medicine of Dong-A University Hospital from April 2014 to January 2016 Exclusion criteria: noncompliance due to cognitive impairment, medical history of stroke, nervous system disease, or musculoskeletal disease, and medical history of injury to an upper extremity or upper chest area or surgery
Interventions	2 groups: 1. robot-assisted therapy with the robot Neuro-X (Apsun Inc., Seoul, Korea) over 20 sessions (30 minutes per session, 2 sessions per day, 5 days a week, for 2 weeks 2. conventional upper extremity rehabilitation exercises twice daily
Outcomes	Outcomes were measured at baseline (week 0), at the end of intervention period (week 2) Outcomes: 1. Spasticity was evaluated using the MAS 2. Manual muscle tests to measure muscle strength 3. Upper extremity motor functions were evaluated using the Manual Function Test (test scores upper extremity exercise, grip strength, and finger manipulation abilities for a possible total of 32 points) 4. Brunnstrom stages show the degree of motor function recovery 5. K-MBI was administered to evaluate degree of self-reliance in daily living activities
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Computerised table of random numbers
Allocation concealment (selection bias)	Low risk	Authors stated: "random procedure was carried out by an independent person"
Blinding of outcome assessment (detection bias) All outcomes	High risk	Not done
Selective reporting (reporting bias)	Unclear risk	Not sufficient information to permit judgement

Liao 2011

Methods	Prospective RCT

Liao 2011 *(Continued)*

	Methods of randomisation: participants were randomly assigned to either the treatment or control group in accordance with a random number table, then a sealed envelope was given to the therapists to deliver therapy accordingly
Participants	Country: Taiwan Sample size: 20 participants (10 in treatment group and 10 in control group) Inclusion criteria: clinical diagnosis of the first cortical or subcortical stroke, more than 6 months post-stroke, initial upper limb FMA score of 28 to 56 (0 to 66), MMSE > 22, no excessive spasticity in elbow or wrist joints of the affected arm (MAS < 3) Exclusion criteria: stroke lesions in other than brain areas (cerebellum or brainstem), comorbidity with other severe neurological diseases (epilepsy), severe shoulder pain or painful arthritis of the elbow, wrist, or finger joints, unable to follow treatment instructions
Interventions	2 groups: 1. group A: participants received robot-assisted therapy (with the Bi-Manu-Track) over 4 weeks, 5 days a week for 90 to 105 minutes per session, with 600 to 800 repetitions of mode 1 (passive-passive mode) and mode 2 (passive-active mode), and 150 to 200 repetitions of mode 3 (active-active or resistance mode). If the participants were able to perform actively forearm pronation-supination or wrist flexion-extension, then mode 2 was adjusted to mode 4 (active-passive mode, but the affected arm would actively execute the training cycle). After robot-training, participants received 15 minutes of training in functional activities that were selected by participants and therapists, e.g. twisting a towel 2. group B: participants received active control therapy that senior occupational therapists designed for protocol-based occupational therapy techniques such as neurodevelopmental techniques with emphasis on functional training, e.g. muscle strengthening of the affected arm and ADL or functional task training. The control group received the same amount of therapy hours as the treatment group (dose-matched comparison group); after the active control therapy session the participants also received 15 minutes of training in functional activities that were selected by the participants and the therapists
Outcomes	Outcomes were recorded at baseline and immediately after the 4 weeks of intervention 1. Arm activity ratio of the accelerometer data (ratio of activity between the affected and the unaffected limb) measured by the MicroMini-Motionlogger activity monitor (Ambulatory Monitoring, New York, NY, USA) 2. FMA 3. FIM 4. MAL 5. ABILHAND
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Random assignment in accordance with a number table to either treatment or control group
Allocation concealment (selection bias)	Low risk	By sealed opaque envelopes
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Blinded assessor

Liao 2011 *(Continued)*

Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Lo 2010

Methods	Multicentre RCT Method of randomisation: a permuted-block design that was stratified according to site
Participants	Country: USA Sample size: 127 participants (49 in intensive robot-assisted group, 50 in intensive comparison group, and 28 in usual care group) Inclusion criteria: age 18 years and older; stroke that occurred at least 6 months prior to enrolment to the study; long term, moderate to severe motor impairment of the upper limb (described as a score between 7 and 38 of the Fugl-Meyer score); and written informed consent from all participants Exclusion criteria: all patients with a baseline Fugl-Meyer score outside the required range of 7 to 38
Interventions	3 groups: 1. group A: the participants received intensive robot-assisted therapy for a maximum of 36 sessions over a period of 12 weeks 2. group B: the participants received intensive comparison therapy, which matched the robot-assisted therapy in schedule and in form of intensity of movements 3. group C: the participants received customary care (i.e. medical management, clinic visits needed, and in some cases rehabilitation services). After the final study visit, the participants in the usual care group were offered to choose between robot-assisted therapy or intensive comparison therapy
Outcomes	Outcomes were recorded at baseline, then 6 and 12 weeks after randomisation, then again 6 months and 9 months after treatment completion 1. FMA 2. WMFT 3. Stroke Impact Scale (SIS 3.0) 4. MAS 5. measure of pain with a scale from 0 to 10
Notes	Groups B and C were collapsed into one control group (pooled as one single group) in our analysis We used all initially included participants in the analysis (according to an intention-to-treat approach)

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Random assignment with a permuted-block design that was according to participants stratified to 1 or the other site of intervention
Allocation concealment (selection bias)	Unclear risk	Insufficient information about the concealment of allocation
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Trained blinded raters

Lo 2010 *(Continued)*

Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Lum 2002

Methods	RCT Method of randomisation: list of random numbers
Participants	Country: USA Sample size: 30 participants (15 in treatment group, 15 in control group) Inclusion criteria: diagnosis of a single stroke, more than 6 months post-stroke, obvious deficit in upper-limb motor function as a result of the stroke, had completed all formal outpatient therapy but continued with any home-based exercise regimen or community-based stroke programmes they were enrolled in at the time of intake into the study Exclusion criteria: upper-extremity joint pain or range-of-motion limitations that would affect their ability to complete the protocols; any unstable cardiovascular, orthopaedic, or neurologic conditions; cognitive impairments if people were unable to cooperate with the study tasks
Interventions	2 groups: 1. control group received 55 minutes of physiotherapy for the arm and 5 minutes of robot training for each of the 24 sessions over a 2-month period 2. experimental group received bimanual and passive robot therapy by the MIME robot for the same time and frequency
Outcomes	Outcomes were recorded at baseline and after 4 and 8 weeks (end of training) and 8 months after baseline 1. FMA 2. Barthel Index 3. FIM 4. strength 5. reach
Notes	Incorporates results of Burgar 2000

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Participants were randomly assigned to either group based on a list of random numbers
Allocation concealment (selection bias)	Unclear risk	Insufficient information about the concealment of allocation
Blinding of outcome assessment (detection bias) All outcomes	Low risk	An occupational therapist blinded to group assignment tested all participants with a battery of clinical evaluations
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Lum 2006

Methods	RCT Method of randomisation: list of random numbers
Participants	Country: USA Sample size: 30 participants (9 in the robot-unilateral group, 10 in the robot-bilateral group, 5 in the robot-combined group, and 6 in the control group) Inclusion criteria: diagnosis of stroke, 1 to 5 months post-stroke Exclusion criteria: any upper-limb joint pain or range-of-motion limitations that would affect their ability to complete the protocols; any unstable cardiovascular, orthopaedic, or neurological conditions; cognitive impairments (scored < 21 of the Folstein MMSE)
Interventions	4 groups: 1. robot-unilateral group performed exercises with the MIME device that progressed from the easiest exercise modes (passive) to the most challenging (active-constrained); no bilateral exercise was performed 2. robot-bilateral group practised the same 12 reaching movements as in group 1, but only in bilateral mode with the MIME device 3. robot-combined group spent approximately half the treatment time in the unilateral mode (as in group 1) and the other half in the bilateral mode with the MIME device 4. control group received an equivalent intensity and duration of conventional therapy targeting proximal upper-limb function based on neurodevelopmental treatment Groups 1 to 3 were collapsed to 1 robot treatment group (pooled as 1 group) in our analysis
Outcomes	Outcomes were recorded immediately before treatment started, immediately post-treatment, and 6 months after treatment ended 1. FMA 2. Motor Status Score 3. FIM 4. Motor Power examination to assess arm strength 5. MAS
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Insufficient information about the sequence generation process
Allocation concealment (selection bias)	Unclear risk	Insufficient information about the concealment of allocation
Blinding of outcome assessment (detection bias) All outcomes	Low risk	An occupational therapist blinded to group assignment tested all participants with a battery of clinical evaluations
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Masiero 2007

Methods	RCT

Masiero 2007 *(Continued)*

	Method of randomisation: not stated
Participants	Country: Italy Sample size: 35 participants (17 in treatment group, 18 in control group) Inclusion criteria: first, single unilateral ischaemic stroke using the World Health Organization definition of stroke Exclusion criteria: neurologic or cardiovascular instability contraindicating exercise (e.g. uncontrolled hypertension), early severe spasticity, multiple cerebrovascular lesions, severe neuropsychologic impairment (global aphasia, severe attention deficit or neglect), not able to follow instructions
Interventions	2 groups: 1. treatment group received additional early sensorimotor robotic training with the NeReBot, robot training treatment twice a day, 5 days a week, for at least 5 weeks 2. control group received similar exposure to the robot (30 minutes twice per week) except that the exercises were performed with the unimpaired arm
Outcomes	Outcomes were recorded at baseline and after 1.5, 3, and 8 months 1. FMA 2. MRC score to measure the strength of shoulder abduction, elbow flexion, and wrist flexion 3. FIM (motor component) 4. Trunk Control Test 5. MAS
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Insufficient information about the sequence generation process
Allocation concealment (selection bias)	Unclear risk	Insufficient information about the concealment of allocation
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Assessments were performed for all participants by the same blinded clinician
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Masiero 2011

Methods	RCT Method of randomisation: sequence of computer-generated random numbers
Participants	Country: Italy Sample size: 21 participants (11 in treatment group, 10 in control group) Inclusion criteria: 1) diagnosis of recent single-sided stroke (ischaemic or haemorrhagic) demonstrated by brain computerised axial tomography or nuclear magnetic resonance, 2) sufficient cognitive and language capacities to understand the operator's instructions (modified MMSE score > 18), 3) paralysis

Masiero 2011 *(Continued)*

	or paresis (Motor Power score between 8 and 12) with no ability for active movement against gravity or weak resistance Exclusion criteria: 1) cardiovascular instability (severe uncontrolled hypertension, severe coronary artery disease, etc.) or orthopaedic or neurological conditions, 2) multiple cerebrovascular lesions, 3) > 3 points on Ashworth Scale, 4) upper-limb joint pain or limitations to range of motion that would have affected the participant's ability to complete the protocols, 5) severe neuropsychological impairment (global aphasia, severe attention deficit, or severe space inattention), 6) age > 85 years or < 18 years
Interventions	2 groups: 1. treatment group received robotic training with the NeReBot, robot training twice a day for 20 minutes, and 40 minutes conventional training, 5 days a week, for at least 5 weeks 2. control group received conventional functional rehabilitation for 80 minutes a day (including proprioceptive exercises, functional re-education, gait training, occupational therapy, and passive and active-assisted mobilisation of the hand and wrist) but without specifically exercising the proximal paretic arm
Outcomes	Outcomes were recorded at baseline, 5 weeks after treatment onset, and after 3-month follow-up: 1. MRC 2. FMA 3. Motor subsection of Functional Independence Measure (m-FIM) 4. MAS 5. Frenchay Arm Test 6. BBT 7. Tolerability of treatment: evaluated by noting the number of medical complications in the 2 groups (shoulder-hand syndrome, shoulder pains) and the degree of acceptance of the robotic training rated on a visual analogue scale (0 = poor acceptance and 10 = maximum acceptance)
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomisation was achieved with use of a sequence of computer-generated random numbers
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Low risk	All participant assessments were performed by the same blinded clinician, who had previously attended a training course qualifying him or her to use the scales, was not directly involved in the delivery of either robot-aided or standard rehabilitation therapy within the study, and did not know which participants had been enrolled in the EG and the CG
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Mayr 2008

Methods	Cross-over RCT Method of randomisation: not stated

Mayr 2008 *(Continued)*

Participants	Country: Austria Sample size: 8 (4 in treatment group, 4 in control group) Inclusion criteria: < 3 months post-stroke with severe to moderate upper-limb paresis, sufficient communication abilities to complete the study, and written informed consent Exclusion criteria: painful arthritis of the wrist and finger or physician-determined major medical problems
Interventions	2 groups: 1. group AB: the participants received over 2 weeks, 5 times per week robot-assisted therapy with the ARMOR device, then 2 weeks with no intervention, and then over 2 weeks, 5 times per week EMG-initiated functional electrical stimulation 2. group BA: the participants received 5 times per week over 2 weeks EMG-initiated functional electrical stimulation, then 2 weeks no intervention, and then 5 times per week over 2 weeks robot-assisted therapy
Outcomes	Outcomes were recorded at baseline and then after each cross-over (after 2, 4, and 6 weeks since baseline) 1. CMSA 2. MAS 3. Jamar dynamometer to measure hand force 4. Functional Dexterity Test
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Random sequence generation (information provided by the investigator)
Allocation concealment (selection bias)	High risk	No concealment of allocation was provided (information provided by the investigator)
Blinding of outcome assessment (detection bias) All outcomes	High risk	Assessors were not blinded (information provided by the investigator)
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement of 'low' or 'high' risk

McCabe 2015

Methods	RCT Method of randomisation: not described
Participants	Country: USA Sample size: 39 participants (12 in the experimental and 27 in the control group)

McCabe 2015 *(Continued)*

	Inclusion criteria: single unilateral stroke; > 1 year upper extremity impairment; a trace muscle contraction in the wrist extensors; mobility and function sufficient for independent performance of activities; stable medical condition; not other neurologic condition; ability to follow 2-step commands; informed consent Exlusion criteria: not explicitly stated
Interventions	3 groups: 1. Motor Learning Programme in a 1:3 group paradigm for 5 hours per day for 12 weeks 2. Motor Learning Programme in a 1:3 group paradigm for 3.5 hours per day + functional electric stimulation for 1.5 hours per day for 12 weeks 3. Motor Learning Programme in a 1:3 group paradigm for 3.5 hours per day + robotic-assisted arm training with the InMotion2 Shoulder-Elbow Robot 1.5 hours per day for 12 weeks
Outcomes	Outcomes were recorded at baseline and post-treatment every 2 weeks Primary outcome: AMAT Secondary outcomes: AMAT subscale wrist/hand; AMAT subscale shoulder/elbow; FMA (shoulder/elbow and wrist/hand subscales); AMAT (function scale)
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Not described
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "There was 1 assessor, who was blinded to the group assignment of the subject."
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

NCT03020576

Methods	RCT
Participants	Country: USA, Austria Sample size: 31 participants (16 in treatment group; 15 in control group) Inclusion criteria: history of stroke (> 3 months from time of ictus), paresis or plegia of the upper extremity Exclusion criteria: severe spasticity (defined on the Ashworth Scale with a score of 4 to 5); severe pain despite conventional pain therapy of the paretic upper extremity; swelling, infection, fracture or ulcers of the paretic extremity; arthritis of the hand joints; pregnant; botulinum toxin therapy to the upper extremity within 3 months prior to study entry; severe contractions
Interventions	2 groups:

NCT03020576 *(Continued)*

	1. robot therapy with the Amadeo Hand robot three times per week for eight weeks, for 60 minutes 2. standard arm therapy for three times per week for eight weeks, for 60 minutes
Outcomes	Outcomes were measured at baseline (week 0), at the end of intervention period (week 8) Primary outcome: 1. change in total FMA score Secondary outcomes: 1. Change in range of motion measures 2. Change in hand and pinch strength 3. Change in Motor Activity Log Amount 4. Change in mobility and ADL 5. Change in hand dexterity 6. Change in spasticity measures 7. Change in Motor Activity Log How Well
Notes	Formerly ongoing study (Helbok 2010)

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Method not described
Allocation concealment (selection bias)	Unclear risk	Insufficient to permit judgement of 'low' or 'high' risk
Blinding of outcome assessment (detection bias) All outcomes	High risk	No blinding of outcome assessors
Selective reporting (reporting bias)	Unclear risk	Unclear because study is not fully published yet and results appear online only

Orihuela-Espina 2016

Methods	RCT
Participants	Country: Mexico Sample size: 17 participants (9 in treatment group; 8 in control group) Inclusion criteria: adult patients (> 30 years old) with a diagnosis of haemorrhagic or ischaemic stroke and who experienced severe upper extremity hemiparesis (estimated by the Fugl-Meyer scale > 8 and < 30) Exclusion criteria: severe pain and instability in the wrist of the affected arm, severe cognitive impairment, aphasia, hemispatial neglect, apraxia and joint contractures greater than 20 in the affected hand, presenting instability of the wrist, MMSE score less than 27 points, not be able to follow instructions, visuospatial hemineglect, apraxia, and aphasia
Interventions	2 groups:

Orihuela-Espina 2016 *(Continued)*

	1. robot therapy with the Amadeo (Inc. Typromotion) for 40 sessions 5 times a week for about 60 minutes 2. classical occupational therapy 40 sessions 5 times a week for about 60 minutes
Outcomes	Outcomes were measured at baseline (week 0), at the end of intervention period (week 8 to 10) Outcomes: total FMA score and Motricity Index
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomisatiion by coin toss
Allocation concealment (selection bias)	Unclear risk	Insufficient information to permit judgement of 'low' or 'high' risk
Blinding of outcome assessment (detection bias) All outcomes	High risk	No blinding was done
Selective reporting (reporting bias)	Low risk	Not aware of selective reporting and all participants were included in the analysis

Rabadi 2008

Methods	RCT Method of randomisation: sealed, opaque envelopes
Participants	Country: USA Sample size: 30 participants (10 in experimental group and 20 in control groups) Inclusion criteria: first acute stroke; time since stroke < 4 weeks; admission to an inpatient rehabilitation facility; arm weakness as defined by MRC grade < 2 in the shoulder joint; informed consent Exlusion criteria: anterior or severe inferior shoulder subluxation (≥ 3 cm) of the affected arm; shoulder pain on passive range of 60° forward flexion and 60° abduction of the weak arm; trophic skin changes and significant oedema (shoulder-hand syndrome); prior rotator cuff surgery; bursitis or biceps tendonitis; recent cardiac event; medications enhancing motor recovery such as Botox or d-amphetamine
Interventions	3 groups: 1. standard occupational and physical therapy for 3 hours per day + 12 additional sessions of 40 minutes of occupational therapy 5 days per week 2. standard occupational and physical therapy for 3 hours per day + 12 additional sessions of 40 minutes of arm ergometry 5 days per week 3. standard occupational and physical therapy for 3 hours per day + 12 additional sessions of 40 minutes of robotic-assisted arm training with the MIT-Manus 5 days per week
Outcomes	Outcomes were recorded at baseline and at discharge Primary outcomes: 1. Shoulder/elbow subscales of FMA wrist/hand subscales

Rabadi 2008 *(Continued)*

2. Motor Status Scale
3. FIM (including motor and cognition subscale)

Secondary outcomes:

1. Motor Power Scale for muscle strength
2. ARAT
3. MAS

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "Patients who consented were randomized by sealed, opaque envelopes in blocks of six (two patients in each group) at a time."
Allocation concealment (selection bias)	Low risk	Quote: "Envelopes were identical for the three groups of patients. These sealed envelopes were kept in a locked place. Participants were assigned to one of the three groups by a designated nurse on the unit not associated with the study."
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "The outcome measures were recorded at baseline and on discharge by an evaluator (LD) blinded to treatment allocation."
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Sale 2014

Methods	RCT Method of randomisation: Lehmer's algorithm
Participants	Country: Italy Sample size: 53 Inclusion criteria: subacute first-ever stroke, unilateral paresis, ability to understand and follow simple instructions, ability to remain in a sitting posture Exlusion criteria: bilateral impairment, severe sensory deficits in the paretic upper limb, cognitive impairment or behavioural dysfunction that would influence the ability to comprehend or perform the experiment, refusal or inability to provide informed consent, other current severe medical problems
Interventions	2 groups: 1. performed 30 sessions of robot-assisted therapy (5 days a week for 6 weeks, goal-directed, planar reaching tasks, which emphasised shoulder and elbow movements, moving from the centre target to each of the 8 peripheral targets MIT-Manus/InMotion2 robot) 2. 30 sessions (5 days a week for 6 weeks) of conventional rehabilitative treatment, matching robot-assisted therapy of the same duration, such as assisted stretching, shoulder and arm exercises, and functional reaching tasks provided by experienced physiotherapists Experimental and control therapies were applied in addition to usual rehabilitation

Sale 2014 *(Continued)*

Outcomes	Outcomes were recorded at baseline, after 3 weeks and post-treatment after 6 weeks 1. FMA 2. MAS-Shoulder and Elbow 3. passive range of motion 4. Motricity Index
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "A Lehemer algorithm was applied to achieve a balanced allocation in the EG and CG groups. Therapists were randomly assigned to patients within each group using the same algorithm."
Allocation concealment (selection bias)	Unclear risk	Quote: "The random allocation to treatment was concealed and based upon dedicated software."
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "The clinical assessments were carried out by blinded assessors..."
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Susanto 2015

Methods	RCT Method of randomisation: random number generator
Participants	Country: China Sample size: 19 Inclusion criteria: primary stroke 6 to 24 months prior to the beginning of the intervention, moderate stroke condition (50 > FMA score > 20), ability to understand simple commands (MMSE score > 21), and ability to differentiate sensation on 1 finger from the other fingers Exclusion criteria: recurrent stroke; other neurological, neuromuscular, or orthopaedic disease; or shoulder or arm contracture/pain
Interventions	2 groups: 1. hand exoskeleton robot-assisted group 2. control group (non-assisted group)
Outcomes	Outcomes were recorded at baseline, within 3 days after the last session, and at 6-month follow-up 1. ARAT 2. WMFT 3. FMA
Notes	

Susanto 2015 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Random number generator
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "single-blinded so the assessors were of no knowledge of the grouping."
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Takahashi 2016

Methods	RCT
Participants	Country: Japan Sample size: 60 participants (30 in treatment group; 30 in control group) Inclusion criteria: clinically incipient stroke patients with upper-limb hemiplegia, expected to be hospitalised in a recovery-phase rehabilitation ward for the duration of the study, experienced a stroke in the previous 4 to 8 weeks, upper limb (shoulder/elbow) Brunnstrom stage III or IV at the time of providing informed consent, age between 20 and 80 years at the time of providing informed consent Exclusion criteria: brainstem stroke, vision disorders, haemorrhagic cerebral infarction (brain haemorrhage immediately after infarction) or subarachnoid haemorrhage, severe aphasia, inability to remain seated during training, intense pain in response to external pressure on affected upper limb, incapable of voluntary consent, previous experience with robotic rehabilitation of upper-limb hemiplegia, previous experience with constraint-induced movement therapy of upper-limb hemiplegia, previous experience with functional electrical stimulation therapy of upper-limb hemiplegia, cardiac or respiratory disorders that may interfere with rehabilitation, other neuromuscular diseases, body weight of 110 kg or more, other reasons deemed by the investigators or subinvestigators to render the patient unsuitable for treatment with the investigational device
Interventions	2 groups: 1. robot therapy with the ReoGo for 40 additional minutes, 7 times a week for 6 weeks 2. therapist-directed self-training for 40 additional minutes, 7 times a week for 6 weeks
Outcomes	Outcomes were measured at baseline (week 0), 6 weeks' follow-up (week 6) Outcomes: 1. Brunnstrom stage: shoulder/elbow 2. FMA: all upper-limb items 3. Simple Test for Evaluating Hand Function: all items 4. Motricity Index: shoulder joint flexion; elbow joint flexion 5. Modified Ashworth Scale: elbow flexors; elbow extensors; forearm pronation; forearm supination 6. WMFT: 15 items 7. Range of motion: shoulder; elbow; forearm; hand

Takahashi 2016 *(Continued)*

Notes

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Authors stated: "by central registration staff using Zelen's method combined with the minimization method to control for confounders"
Allocation concealment (selection bias)	Low risk	Authors stated: "by central registration staff"
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Authors stated: "Evaluation of efficacy will therefore be undertaken by physicians who are not present during the training or by OTs or PTs participating in an instructional capacity, so blindness and objectivity will be maintained among these evaluators by withholding the details of subject assignment."
Selective reporting (reporting bias)	Unclear risk	Some of the participants included were not reported at the end

Taveggia 2016

Methods	RCT
Participants	Country: Italy Sample size: 54 participants (27 in treatment group; 27 in control group) Inclusion criteria: a history of acute phase of stroke; first stroke episode; no history of peripheral nerve injury or musculoskeletal disease (e.g. arthritis, musculotendinous injury or bone fracture) in the affected upper extremity; no contracture of the affected wrist or fingers (MAS < 3); and no history of any invasive procedure (botulinum toxin type A) for the treatment of spasticity for at least 6 months prior to the start of this study Exclusion criteria: unstable medical disorders, aphasia, or cognitive problems (MMSE ≤ 21)
Interventions	2 groups: 1. robot therapy with the Armeo Spring for 30 minutes per session, 5 times per week for 6 weeks 2. physical rehabilitation therapy (according to the Bobath concept) for 30 minutes per session, 5 times per week for 6 weeks
Outcomes	Outcomes were measured at baseline (week 0), at the end of intervention period (week 6), at follow-up (further 6 weeks later) Outcomes: 1. FIM 2. Motricity Index 3. MAS 4. Numeric Rating Pain Scale
Notes	

Risk of bias

Taveggia 2016 *(Continued)*

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Computer-generated random list
Allocation concealment (selection bias)	Low risk	Randomly assigned by an external assistant
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Authors stated: "assessor blinded"
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Timmermans 2014

Methods	RCT Method of randomisation: blocked randomisation, using opaque envelopes
Participants	Country: the Netherlands Sample size: 22 Inclusion criteria: first-ever stroke, age between 18 and 85 years, clinically diagnosed with a central paresis of the arm/hand (strength: MRC grade 2 to 4 at entry into study), post-stroke time ≥ 12 months, fair to good cognitive level (MMSE score ≥ 26), able to read and understand the Dutch language, unable to fully perform at least 2 of the following skills: drinking from a cup, eating with knife and fork, taking money from a purse and using a tray; motivated to train in at least 2 of the above-mentioned skills. (At the start of the last 6 months of the inclusion period, inclusion criteria were adjusted to post-stroke time ≥ 8 months, to facilitate participant inclusion) Exclusion criteria: severe neglect (Bell Test, Letter Cancellation Test: minimum omission score of 15%), hemianopsia, severe spasticity (MAS total arm > 3, severe additional neurological, orthopaedic, or rheumatoid impairments prior to stroke that could interfere with task performance, Broca's aphasia, Wernicke's aphasia, global aphasia (determined by the Akense Afasie Test), apraxia (apraxia test of Van Heugten), and attending another study or therapy to improve arm-hand function
Interventions	2 groups: 1. robotic-assisted training with the end-effector robot HapticMaster 2. arm-hand training programme (control group) Training was provided during 8 weeks, 4 times/week, twice a day for 30 minutes (separated by 0.5 hour to 1 hour of rest)
Outcomes	Outcomes were recorded at baseline and post-treatment every 2 weeks 1. FMA 2. ARAT 3. MAL (quality of use (QU) and amount of use (AU)) 4. EuroQol-5D (visual analogue scale) 5. SF-36
Notes	

Timmermans 2014 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "participants were randomly allocated to ... using blocked randomization (block size = 2). The randomization procedure was performed by an independent researcher using 2 opaque envelopes, within each envelope a training condition code."
Allocation concealment (selection bias)	Low risk	Quote: "The randomization procedure was performed by an independent researcher using 2 opaque envelopes, within each envelope a training condition code."
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "Persons involved in data collection were blinded for group allocation."
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Tomic 2017

Methods	RCT
Participants	Country: Serbia Sample size: 26 participants (13 in treatment group; 13 in control group) Inclusion criteria: unilateral paresis as a result of first ischaemic or haemorrhagic stroke confirmed by CT or MRI that occurred less than 3 months before enrolment, the ability to understand and follow simple instructions, the ability to perform some active movements in the shoulder or elbow joints, or both, in the sitting position, allowing for trunk compensation if needed Exclusion criteria: multiple strokes, bilateral impairment, severe sensory deficits in the paretic upper limb, the inability to provide informed consent, and medical conditions that could interfere with treatment (severe cardiovascular disease, severe visual or auditory impairments, and orthopaedic contracture)
Interventions	2 groups: 1. additional robot therapy with the ArmAssist (AA) for 30 minutes administered over 15 sessions each lasting 30 minutes, scheduled 5 days per week (Monday to Friday) for 3 weeks, 2. additional occupational therapy for 30 minutes that was matched in its structure and amount to the AA training as close as possible and administered over 15 sessions each lasting 30 minutes, scheduled 5 days per week (Monday to Friday) for 3 weeks
Outcomes	Outcomes were measured at baseline (week 0), and at the end of intervention period (week 3) Primary outcome: 1. total FMA score Secondary outcome: 1. WMFT 2. Barthel Index

Tomic 2017 *(Continued)*

Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Table of random numbers
Allocation concealment (selection bias)	Unclear risk	Insufficient information to permit judgement of 'low' or 'high' risk
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Blinded physiotherapist
Selective reporting (reporting bias)	Low risk	No missing outcome data

Vanoglio 2017

Methods	RCT
Participants	Country: Italy Sample size: 30 participants (15 in treatment group; 15 in control group) Inclusion criteria: age > 18 years, patients affected by stroke from cerebral ischaemia or haemorrhage that had occurred ≤ 30 days before, with Ashworth spasticity index < 3 Exclusion criteria: orthopaedic limitation (amputations, irreducible articular limitations, advanced osteoarthritis, active rheumatoid arthritis); peripheral nerve injury; uncontrolled inflammation; severe cognitive and behavioural disorders; neurodegenerative and neuromuscular diseases; Ashworth Spasticity index ≥ 3
Interventions	2 groups: 1. robot therapy with the Gloreha Professional (Idrogenet, Lumezzane, Italy) consisted of a total of 30 sessions, lasting 40 minutes per day, for 5 days per week 2. passive arm therapy for the same amount of therapy
Outcomes	Outcomes were measured at baseline (week 0), and at the end of intervention period (after 30 days) Outcomes: 1. Motricity Index 2. Nine Hole Peg Test 3. Grip and Pinch test 4. Quick DASH
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement

Vanoglio 2017 *(Continued)*

Random sequence generation (selection bias)	Low risk	Computerised random numbers
Allocation concealment (selection bias)	Low risk	Randomisation procedure was conducted independently from the study investigators, and authors used central randomisation
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Blinding of outcome assessors was done
Selective reporting (reporting bias)	Unclear risk	Insufficient reporting of attrition/exclusions to permit judgement of 'low' or 'high' risk

Villafane 2017

Methods	RCT
Participants	Country: Italy Sample size: 32 participants (16 in treatment group; 16 in control group) Inclusion criteria: history of acute phase of stroke, first stroke episode, no history of peripheral nerve injury or musculoskeletal disease (e.g. arthritis, musculotendinous injury, or bone fracture) in the affected upper extremity, no contracture of the affected wrist or fingers (MAS < 3),and no history of any invasive procedure (botulinum toxin type A) for the treatment of spasticity for at least 6 months prior to the start of this study, and paralysis of the wrist and fingers and absence in voluntarily initiating and controlling finger extension movements Exclusion criteria: unstable medical disorders, active complex regional pain syndrome, severe spatial neglect, aphasia, or cognitive problems, > 4 points on the Beck Depression Inventory or more than 30 points in the State Trait Anxiety Inventory
Interventions	2 groups: 1. robot therapy with the hand Gloreha for 30 minutes for 3 days per week 2. physical and occupational arm therapy for the same amount and intensity
Outcomes	Outcomes were measured at baseline (week 0), and at the end of intervention period (week 3) Outcomes: 1. NIH Stroke Scale 2. MAS 3. Barthel Index 4. Motricity Index 5. QuickDASH (short version of the Disabilities of the Arm, Shoulder and Hand) 6. visual analogue scale
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Method of randomisation unclear because described as "simple randomization"

Villafane 2017 *(Continued)*

Allocation concealment (selection bias)	Unclear risk	Insufficient information to permit judgement of 'low' or 'high' risk
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Blinded outcome assessors
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement of 'low' or 'high' risk

Volpe 2000

Methods	RCT Method of randomisation: not stated
Participants	Country: USA Sample size: 56 participants (30 in treatment group, 26 in control group) Ambulatory at study onset Inclusion criteria: first, single stroke, hemiparesis or hemiplegia of the upper and lower extremity, to be able to follow simple instructions, written informed consent Exclusion criteria: not stated
Interventions	2 groups: 1. treatment group used the MIT-Manus device for arm training for 1 hour per day, 5 days a week (for at least 25 sessions) 2. control group had similar initial exposure to the robot with the exception that half the tasks were performed with the unimpaired arm, and when the participant could not perform the task with the affected limb, the unimpaired limb was used to complete the task or the technician assisted the movement. The robot never actively moved the limbs of participants in the control group. Participants were exposed to the robot 1 hour per week
Outcomes	Outcomes were recorded before and after end of treatment 1. FMA 2. Motor Power Score (0 to 20) 3. Motor Status Score for shoulder and elbow (0 to 40) 4. Motor Status Score for wrist and hand (0 to 42) 5. FIM (motor and cognition score)
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Insufficient information about the sequence generation process
Allocation concealment (selection bias)	Unclear risk	Insufficient information about the concealment of allocation
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Participants and the medical and rehabilitation team providing the clinical care were "masked" to the group assignment

Volpe 2000 *(Continued)*

Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Volpe 2008

Methods	RCT Method of randomisation: not stated
Participants	Country: USA Sample size: 21 participants (11 in treatment group, 10 in control group) Inclusion criteria: people after stroke with impaired arm and hand mobility for at least 6 months Exclusion criteria: not able to follow simple instructions, minimally impaired (FMA shoulder-elbow section > 33 points), neurosurgical procedure, second stroke, fixed contracture
Interventions	2 groups: 1. control group: intensive movement protocol with a trained physiotherapist 2. treatment group: robotic training with the InMotion2 robot (the commercial version of MIT-Manus) All participants had an identical number of treatment sessions, and the sessions were of the same duration (1 hour per session, 3 times a week for 6 weeks)
Outcomes	Outcomes were recorded at 3 preliminary evaluations (Pre1, Pre2, Pre3), at midpoint, at discharge, and at 3-month follow-up 1. FMA 2. Motor Power Scale for shoulder/elbow (0 to 70) 3. MAS 4. Stroke Impact Scale (SIS 2.0) 5. ARAT 6. shoulder dislocation (joint stability; maximum cm of displacement = 9) 7. pain scale from the FMA (0 to 24) 8. Beck Depression Scale (maximum = 63)
Notes	

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	Insufficient information about the sequence generation process
Allocation concealment (selection bias)	Unclear risk	Insufficient information about the concealment of allocation
Blinding of outcome assessment (detection bias) All outcomes	High risk	No blinding of outcome assessment was done
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Wolf 2015

Methods	RCT
Participants	Country: USA Sample size: 99 participants (51 in treatment group; 48 in control group) Inclusion criteria: unilateral ischaemic or haemorrhagic stroke within the previous 6 months confirmed by neuroimaging; persistent hemiparesis with some upper limb voluntary movement, as indicated by a score of 11 to 55 on the FMA; ineligibility to receive any further upper-extremity therapy; and preserved cognitive function (Short Portable Mental Status Questionnaire) Exclusion criteria: inability to provide informed consent; not independent before the stroke (determined by score > 1 on the Modified Rankin Scale); hemispatial neglect as determined by > 3 errors on the Star Cancellation Test; sensory loss ≥ 2 on the sensory item of the NIH Stroke Scale; hypertonic affected arm as indicated by a score ≥ 3 on the MAS; antispasticity injection in hemiparetic arm since onset of the stroke; presence of upper-extremity pain or uncorrected vision problems; unmanaged psychiatric issues; and terminally ill with an anticipated survival of less than 1 year
Interventions	2 groups: 1. robot therapy with the Hand Mentor Pro (Kinetic Muscles Incs) for 60 minutes over a 8 (to 12) weeks period 2. home exercises for the arm therapy for 60 minutes over a 8 (to 12) weeks period
Outcomes	Outcomes were measured at baseline (week 0), and at the end of intervention period (week 8 to 12) Primary outcome: 1. Action Research Arm Test Secondary outcomes: 1. WMFT 2. FMA - Arm
Notes	Formerly ongoing study Linder 2013 (NCT01144715)

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Computer-driven randomisation procedure
Allocation concealment (selection bias)	Unclear risk	Insufficient information to permit judgement of 'low' or 'high' risk
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Blinding of outcome assessors was done
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement of 'low' or 'high' risk

Wu 2012

Methods	RCT

Wu 2012 *(Continued)*

	Method of randomisation: not described
Participants	Country: Taiwan Sample size: 42 Inclusion criteria: unilateral stroke at least 6 months previously, mild to moderate motor impairment (total score of 26 to 66 on the upper extremity part of the FMA, no severe spasticity in the paretic arm (MAS score of 2 in any joint), no serious cognitive deficits (MMSE score of 22), no other neurologic, neuromuscular, or orthopaedic disease and no participation within the previous 3 months in any experimental rehabilitation or drug studies Exclusion criteria: none described
Interventions	3 groups: 1. therapist-mediated bilateral arm training group 2. robot-assisted (Bi-Manu-Track) arm trainer (RAT Group) 3. CT involved weight bearing, stretching, strengthening of the paretic arms, coordination, unilateral and bilateral fine-motor tasks, balance, and compensatory practice on functional tasks Each group received treatment for 90 to 105 minutes per session, 5 sessions on weekdays, for 4 weeks
Outcomes	Outcomes were recorded at baseline and post-treatment after 4 weeks 1. Kinematic analysis 2. FMA 3. MAL (quality of use and amount of use) 4. SIS
Notes	We combined the results of both the first and the third groups (the non-robot groups) in 1 (collapsed) group and compared this collapsed group with the results of the RAT group

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Exact method not described
Allocation concealment (selection bias)	Low risk	Quote: "The allocation to group was concealed from the investigators"
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "The participants were blinded to the study hypotheses." and "Clinical outcome measures were administered ... by ... therapists blinded to the participant group."
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

Yoo 2013

Methods	RCT Method of randomisation: not clearly described
Participants	Country: South Korea

Yoo 2013 *(Continued)*

	Sample size: 22 Inclusion criteria: no visual neglect or impaired cognitive function (MMSE score > 24 points), written informed consent Exlusion criteria: none
Interventions	2 groups: 1. 3-dimensional robot-assisted therapy (RAT) and conventional rehabilitation therapy (CT) for a total of 90 minutes (RAT: 30 minutes, CT: 60 minutes) a day with 10 minutes rest halfway through the session, received training 3 days a week for 6 weeks 2. the control group received only CT for 60 minutes a day on the same days as the first group
Outcomes	Outcomes were recorded at baseline and post-treatment after 6 weeks 1. WMFT 2. BBT 3. modified Barthel Index
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote: "Subjects were randomly assigned to..." The method of randomisation was not described
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "Patients and investigators were blind to the test results and intervention grouping because this study used a double-blinded design."
Selective reporting (reporting bias)	Unclear risk	Insufficient information to permit judgement

AA: Arm Assist
ABILHAND: a measure of manual ability for people with upper limb impairment.
ADL: activities of daily living
AMAT: Arm Motor Ability Test
ARAT: Action Research Arm Test
ARMin: arm robot
BBT: Box and Block Test
BCI-HK: brain computer interface with haptic knob device
CAHAI-7:Chedoke Arm and Hand Activity Inventory
CG: control group
CIT: constraint-induced therapy
CMSA: Chedoke-McMaster Stroke Assessment
CRT: conventional rehabilitation therapy
CT: computed tomography
DASH: Disabilities of the Arm, Shoulder and Hand
EG: experimental group
EMG: electromyography
EuroQol-5D: standardized instrument for measuring generic health status

FES: functional electrical stimulation
FIM: Functional Independence Measure
FMA: Fugl-Meyer Assessment
K-MBI: Korean modified version of the Barthel Index
MAL: Motor Activity Log
MAS: Modified Ashworth Scale
MIME: mirror image motion enabler
min: minimum
MIT-Manus: robotic device developed at the Massachusetts Institute of Technology
MMSE: Mini Mental State Examination
MRC: Medical Research Council
MRI: magnetic resonance imaging
NIH: National Institutes of Health
OT: occupational therapy
RAT: robot-assisted therapy
RCT: randomised controlled trial
Robot-Lo: robot training with low intensity
RT: robot training
SD: standard deviation
SF-36: short form 36
SIS: Stroke Impact Scale
TENS: transcutaneous electrical nerve stimulation
WMFT: Wolf Motor Function Test

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

Study	Reason for exclusion
Abdollahi 2014	Compared 2 different approaches of robotic training
Aisen 1997	Not an RCT; participants were allocated by stratification not by randomisation; inclusion criteria not fulfilled
Chua 2010	All included participants received a kind of robotic therapy
Dodakian 2013	Not an RCT; participants were allocated using an approach that kept age and baseline motor deficits matched across the 2 groups
Fasoli 2003	All included participants received a kind of robotic therapy
Fluet 2012	Irrelevant comparison: 2 different approaches of robotic training tested
Hill 2011	Not an electromechanical-assistive device; used functional electrical stimulation only
Hu 2009	All included participants received a kind of robotic-assisted/device-assisted therapy
Hu 2015	Irrelevant comparison: 2 different approaches of robotic training tested
Jackson 2013	Not an RCT; description of a project/plan for RCT
Krebs 2000	Not an RCT
Luft 2004	Inclusion criteria of robot-aided or electromechanical-assisted technology not fulfilled; device used is a mechanical device without robot aid and without an electromechanical-assisted technology
Lum 2004a	Not an RCT

Study	Reason for exclusion
Lum 2004b	This trial was excluded after correspondence with the study authors because it overlaps with another trial included in the analysis
NCT0040766707	All participants received the same robotic therapy
Page 2012	Not an electromechanical-assistive device; used functional electrical stimulation only
Peters 2017	Did not fulfil our inclusion criteria for electromechanical-assistive device
Prange 2015a	Not an electromechanical-assistive device; used sling support and feedback only
Prange 2015b	Did not fulfil our inclusion criteria for electromechanical-assistive device
Reinkensmeyer 2000	Not an RCT
Samsygina 2010	Did not investigate electromechanical-assistive therapy
Simkins 2016	2 robotic intervention groups: 2-armed, mirror-imaged and 1-armed
Sun 2016	Full English text unavailable
Takahashi 2008	No strict randomisation process; inclusion criteria not fulfilled
Takebayashi 2013	Not a genuine RCT
Thorsen 2013	Investigated myoelectrically controlled functional electrical stimulation
Tropea 2013	Irrelevant comparison: 2 different approaches of robotic training were tested
Volpe 1999	Not an RCT
Wang 2007	Did not fulfil our inclusion criteria for electromechanical-assistive device
Whitall 2000	Inclusion criteria of robot-aided or electromechanical-assisted technology not fulfilled; device used was a mechanical device without robot aid and without an electromechanical-assisted technology
Willigenburg 2017	Did not fulfil our inclusion criteria for electromechanical-assistive device
Yoo 2015	Not an RCT
Zahi 2017	Full English text unavailable

RCT: randomised controlled trial

Characteristics of studies awaiting assessment *[ordered by study ID]*

Chisari 2014

Methods	RCT
Participants	Country: Italy Sample size: 18 Inclusion criteria: chronic stroke

Chisari 2014 *(Continued)*

	Exclusion criteria: not described
Interventions	2 groups: 1. robotic therapy delivered with a robotic exoskeleton 2. manual physical therapy The treatments were matched in terms of intensity, duration, and tasks
Outcomes	1. FMA 2. Modified Ashworth Scale 3. Bimanual Activity Test 4. execution time and smoothness index
Notes	

Esquenazi 2017

Methods	RCT
Participants	Country: USA 15 participants with unilateral hemiparesis with minimum FMA score of 8/66 or Modified Ashworth Scale score of < 3 receiving usual minimum of 3 hours of daily therapy
Interventions	2 groups, conventional or robotic additional upper extremity exercise
Outcomes	Number of completed sessions; withdrawals; serious/adverse events and functional parameters data: FMA, Functional Independence Measure (FIM) and FIM efficiency
Notes	Prelimary results of an ongoing study based on data about 15 acute post stroke patients of < 2 months. Mean age was 66 years. More than half of the participants were male (64%) and most participants presented with left-sided paresis (79%). Embolic and ischaemic strokes were similarly represented (36%) and 29% of haemorrhagic stroke. 1 participant withdrew for personal reasons prior to his first session. All 14 participants (8 robotic, 6 conventional) continued their training sessions until discharge. Of a total of 80 training sessions, 15 were incomplete. Adverse events ranged from upper limb pain; fatigue; gastrointestinal symptoms interfering with training; and falls that occurred unrelated to their study participation Full study results unavailable

Faran 2008

Methods	RCT
Participants	Countries: USA, Germany 20 participants between 3 weeks and 3 months post-stroke
Interventions	2 groups, 20 sessions of either Reo-Therapy system (Motorika USA Inc., NJ) or air splint therapy
Outcomes	• FMA • ARAT • Motor Power Score

Faran 2008 *(Continued)*

	• Motor Status Score
Notes	

Joo 2014

Methods	RCT
Participants	Country: Korea 31 subacute stroke patients
Interventions	2 groups: 1. robot-assisted arm training group received 4 weeks robot-assisted arm training using the Armeo Spring (Hocoma Inc., Zurich, Switzerland) for 30 minutes per day, 5 times per week for 4 weeks 2. control group received conventional arm training with same duration and frequency as robotic group
Outcomes	1. Manual muscle test (MMT) for motor strength 2. FMA 3. Manual function test (MFT) for arm function 4. Korean-modified Barthel index (K-MBI) for ADL 5. Korean-mini mental state examination (K-MMSE) and Computerized Neuro-Cognitive Function test software (CNT-40) for cognitive function
Notes	Full English text unavailable

NCT00435617

Methods	RCT
Participants	Country: USA Inclusion criteria: 3 to 12 months post-stroke; able to extend wrist and fingers at least 10°; functional hearing and vision; able to follow instructions; lives at home, not institution; stable medications for 3 months Exclusion criteria: excessive cognitive impairments; taking/receiving medicines/shots to make arm/hand less stiff; severe pain in the impaired arm; stroke was more than 12 months ago
Interventions	Experimental group: electromechanical-assisted hand therapy at home for 6 weeks (device: Hand Mentor) Control group: not described
Outcomes	Primary outcome: WMFT Secondary outcomes: compliance with recommended use, FMA, SIS
Notes	Estimated enrolment: 70 participants

Reinkensmeyer 2012

Methods	RCT

Reinkensmeyer 2012 *(Continued)*

Participants	Country: USA Sample size: 27 Inclusion criteria: single ischaemic or haemorrhagic stroke; time since stroke at least 3 months; upper extremity FMA between 10 to 35 out of 66; written informed consent Exclusion criteria: significant pain; instability or subluxation of the affected shoulder; cognitive dysfunction interfering with the study tasks; visual deficits; severe neglect or apraxia; current other upper extremity therapy
Interventions	Experimental group: 24 x 1-hour treatment sessions with the Pneu-WREX device, 3 times a week for 8 to 9 weeks Control group (active): conventional exercises typical of home exercise programs, including self range-of-motion stretches, active range-of-motion strengthening exercises, and ADL tasks plus 30 minutes training on the Pneu-WREX per week
Outcomes	Outcomes were collected at baseline, at the end of intervention phase, and at 3-month follow-up Primary outcome measures: FMA Other outcome measures: Rancho Functional Test for the Hemiplegic/Paretic Upper Extremity; MAL; BBT; Nottingham Sensory Assessment
Notes	

Seo 2014

Methods	RCT
Participants	18 hemiplegic patients due to brain lesions
Interventions	2 groups: 1. robot-assisted upper limb training and conventional upper limb physical therapy for 30 minutes a day, respectively (robot group) 2. conventional upper limb physical therapy for 30 minutes twice a day (conventional group) All interventions were provided for 2 weeks, 5 times a week
Outcomes	Each participant was evaluated at pre- and post-treatment by the FMA-upper extremity, Jebsen hand function test (JHFT), grip power, modified Barthel Index-upper extremity (MBI-UE), line bisection test, and Albert test
Notes	Full English text unavailable

ADL: activities of daily living
ARAT: Action Research Arm Test
BBT: Box and Block Test
CNT-40: computerised cognitive test
FIM: Funtional Independence Measure
FMA: Fugl-Meyer Assessment
JHFT: Jebsen-Hand-Function-Test
K-MBI: Korean modified Version of the BI
K-MMSE: Korean version of the Mini mental state examination

MAL: Motor Activity Log
MBI-UE: modified BI for the upper limb
MFT: manual function test
MMT: manual muscle test
RCT: randomised controlled trial
SIS: Stroke Impact Scale
WMFT: Wolf Motor Function Test

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

Krebs 2007

Trial name or title	Robot-aided neurorehabilitation: a robot for wrist rehabilitation
Methods	RCT
Participants	Country: USA Inclusion criteria: first, single focal unilateral lesion with diagnosis verified by brain imaging (MRI or CT scans) that occurred at least 6 months prior; cognitive function sufficient to understand the experiments and follow instructions (MMSE score of 22 or higher or interview for aphasic participants), Motor Power Score 1/5 and 4/5 (neither hemiplegic nor fully recovered motor function in the muscles of the shoulder and elbow and wrist), never experienced robot-assisted therapy, given informed written consent to participate in the study Exclusion criteria: fixed contraction deformity in the affected limb
Interventions	4 groups: 1. 6 weeks of robot-delivered wrist therapy followed by 6 weeks of robot-delivered shoulder-and-elbow training (3 times per week; 36 sessions in total) 2. 6 weeks of shoulder-and-elbow training followed by 6 weeks of wrist training (3 times per week; 36 sessions in total) 3. 12 weeks of alternating days of shoulder-and-elbow and wrist training (with at least 24 hours between alternations) using the planar and wrist robots in stand-alone mode (3 times per week; 36 sessions in total) 4. 12 weeks of training with half of the day's session focusing on shoulder-and-elbow training and half of the session focusing on wrist training (3 times per week; 36 sessions in total) using the planar and wrist robots in stand-alone mode
Outcomes	Primary outcomes: FMA (shoulder/elbow and wrist/hand subsections); motor power
Starting date	Not described
Contact information	Principal Investigator: Hermano Igo Krebs, PhD, Principal Research Scientist & Lecturer, Massachusetts Institute of Technology, Mechanical Engineering Department, 77 Massachusetts Ave, 3-137 Cambridge, MA 02139 USA, Tel: +1 617 253 8112, Fax: +1 617 258 7018, hikrebs@mit.edu
Notes	Estimated enrolment: 160 participants

NCT00272259

Trial name or title	Robots for stroke survivors
Methods	RCT
Participants	Country: USA Inclusion criteria: 1 year post-stroke and difficulties with picking up small objects

NCT00272259 *(Continued)*

	Exclusion criteria: not described
Interventions	Not described
Outcomes	Primary outcomes: not described
Starting date	Not described
Contact information	Bambi Brewer, Carnegie Mellon University, Pittsburgh, Pennsylvania, USA, Tel: +1 412-241-9423, bambi@andrew.cmu.edu Study chairs or principal investigators: 1. Yoky Matsuoka, PhD, Principal Investigator, Carnegie Mellon University 2. Roberta Klatzky, PhD, Study Director, Carnegie Mellon University
Notes	Assessed on 27 May 2015

NCT00343304

Trial name or title	Pilot study - Comparison of upper body ergometer versus robot in upper extremity motor recovery post-stroke
Methods	RCT
Participants	Country: USA Participants: estimated enrolment n = 30 Inclusion criteria: age between 19 and 90 years; stroke in the last 4 weeks; UE plegia (MRC grade ≤ 2 at the shoulder joint); written informed consent; being able to follow simple directions Exclusion criteria: anterior or severe inferior shoulder subluxation (≥ 3 cms) of the plegic arm; no shoulder pain on passive range of 75° forward flexion and 75° abduction of the plegic arm; trophic skin changes and significant oedema; prior rotator cuff surgery; people with bursitis or biceps tendonitis, or both; recent cardiac events
Interventions	Experimental group: unilateral arm training with a robot Control group: bilateral arm training with upper body ergometer
Outcomes	Not described
Starting date	
Contact information	
Notes	This study has been completed. No study results posted

NCT00453843

Trial name or title	The effect of proximal and distal training on stroke recovery
Methods	RCT

NCT00453843 *(Continued)*

Participants	Country: USA Estimated enrolment: 160 participants Inclusion criteria: never experienced robot-assisted therapy; first, single focal unilateral lesion with diagnosis verified by brain imaging (MRI or CT scans) that occurred at least 6 months prior; cognitive function sufficient to understand the experiments and follow instructions (MMSE score of 22 and higher or interview for aphasic participants); average Motor Power score ≥ 1/5 or ≤ 3/5 (neither hemiplegic nor fully recovered motor function in 6 muscles of the shoulder, elbow, and wrist); informed written consent to participate in the study Exclusion criteria: fixed contraction deformity in the affected limb
Interventions	Robotic arm training; no further description
Outcomes	Primary outcome measures: FMA, Motor Power Secondary outcomes: WMFT, SIS
Starting date	June 2004
Contact information	Principal Investigator: Hermano Igo Krebs, PhD, Principal Research Scientist & Lecturer, Massachusetts Institute of Technology, Mechanical Engineering Department, 77 Massachusetts Ave, 3-137 Cambridge, MA 02139, USA, Tel: +1 617 253 8112, Fax: +1 617 258 7018, hikrebs@mit.edu
Notes	

NCT00785343

Trial name or title	Effectiveness of adding robotic therapy to conventional therapy for acute stroke patients with upper extremity paresis
Methods	RCT
Participants	Country: USA Participants: estimated enrolment n = 40 Inclusion criteria: age between 65 and 84 years; right hemispheric unilateral ischaemic stroke; time since stroke < 15 days; arm weakness; right-handedness; MRC grade ≥ 2; being able to follow 2-3 step commands; head, neck, and trunk control; maintain upright posture for at least 45 minutes; some synergistic movements at shoulder flexion or abduction > 30°; ≥ 45° elbow flexion Exclusion criteria: previous stroke; haemorrhagic, cerebellar stroke or subarachnoid haemorrhage; contractures in the involved upper extremity; moderate to severe muscle tone in the involved upper extremity; full, active isolated movement of the involved upper extremity; corrected visual acuity worse than 20/50 for distance; cognitive or other deficits that would negatively affect their ability to follow directions or track visual targets; unstable cardiovascular, orthopaedic, or neurological conditions that would preclude exercise in short-duration, high-workload trials
Interventions	Experimental group: ReoGo robotic arm trainer additional to conventional therapy Control group: conventional therapy
Outcomes	Outcomes will be collected at baseline and at study end Primary outcomes: FMA Secondary outcomes: EMG - muscle activation and co-contraction index

NCT00785343 *(Continued)*

Starting date	September 2008
Contact information	Lauren McDonagh, PT; lmcdonagh@KESSLER-REHAB.com Christine Post, OT; CHPost@selectmedicalcorp.com
Notes	

NCT00878085

Trial name or title	fMRI and robot-assisted practice of activities of daily living
Methods	RCT
Participants	Country: USA Participants: estimated enrolment n = 61 Inclusion criteria: age between 30 to 85 years; right-handedness; unilateral ischaemic stroke in the motor control area with resulting hemiparesis in the arm; time since stroke at least 6 months; residual movement of at least 15° shoulder flexion or adduction and 15° active elbow flexion and extension; no claustrophobia; not depressed; passes the fMRI scanner; being able to understand the instructions and complete the tracking tasks; no history of neurological disorders Exclusion criteria: brainstem stroke; spasticity > 3 at elbow or fingers on Ashworth Scale; visuospatial, language, or attention deficits of a severity that prevents understanding of the task; shoulder pain or joint pain during movements; decline to participate; will not comply with full protocol; pregnant; allergic to Gore-Tex and conductivity gel
Interventions	Experimental group: robot therapy with ADLs 3 times a week for 4 weeks Control group: occupational therapy 3 times a week for 4 weeks
Outcomes	Outcomes will be collected at baseline, at the end of study, and at follow-up Primary outcomes: 1. FMA 2. functional hand evaluation (ADL) 3. Jebsen-Taylor 4. movement time 5. grasp aperture 6. movement smoothness 7. BOLD response (activation) 8. laterality index 9. fractional anisotropy 10. fibre density index Secondary outcomes: 1. joint range of motion 2. manual muscle test 3. spasticity 4. pain 5. exertion

NCT00878085 *(Continued)*

Starting date	November 2008
Contact information	Michel Torbey, MD; Medical College of Wisconsin
Notes	This study has been completed. No study results posted

NCT01117194

Trial name or title	Rehabilitation robot for upper limbs, component project 5: effect on shoulder training using rehabilitation robot for stroke patients
Methods	RCT
Participants	Country: Taiwan Participants: estimated enrolment n = 12 Inclusion criteria: not described Exclusion criteria: not described
Interventions	2 groups: 1. experimental group: shoulder training with the (self developed) NTUH Model One device 2. control group: no intervention
Outcomes	Outcomes will be measured at 1-year follow-up Primary outcomes: 1. Barthel Index 2. MAS 3. Stroke Rehabilitation Assessment of Movement Measure 4. Postural Assessment Scale for Stroke Patients Secondary outcomes 1. shoulder range of motion 2. visual analogue scale
Starting date	January 2010
Contact information	Wen-Shiang Chen, MD, PhD; wenshiang@gmail.com
Notes	

NCT01253018

Trial name or title	Evaluation of robot assisted neuro-rehabilitation (SRT3)
Methods	RCT
Participants	Country: USA Participants: estimated enrolment n = 75

NCT01253018 *(Continued)*

	Inclusion criteria: age over 21 years; clinically defined unilateral hemiparetic stroke (radiologically confirmed); adequate language and cognitive function to participate in training, testing, and informed consent; FMA score with a range of 7 to 38 in the study arm; stroke onset at least 6 months for ischaemic and at least 1 year for haemorrhagic stroke Exclusion criteria: seizures or treatment with anticonvulsants in the past 10 years (for transcranial magnetic stimulation testing); any medication known to interfere with brain stimulation; serious complicating medical conditions, contractures, or orthopaedic problems in the study arm limiting the range of motion for study positions; serious visual loss; Botox injection 3 months prior to enrolment; any change in the exercise regimen involving the study arm
Interventions	Experimental group: 12 weeks of robot therapy consisting of a progression through 3 robot modules: wrist, planar, and alternating wrist and planar robot. The progression will be sequential, with 4 weeks of training on each robotic device Control group: 12 weeks of task-specific practice of functional activities using the hemiparetic arm
Outcomes	Outcomes will be collected at baseline and at the end of study Primary outcomes: FMA Secondary outcomes: motor cortex excitability via transcranial magnetic stimulation
Starting date	April 2011
Contact information	Christopher Bever, MD; Baltimore VA Medical Center VA Maryland Health Care System, Baltimore, MD
Notes	

NCT01552733

Trial name or title	Robotic therapy early after stroke events
Methods	RCT
Participants	Country: UK Participants: estimated enrolment n = 80 Inclusion criteria: age above 18 years; confirmed diagnosis of stroke; randomisation by 7 days; upper limb impairment (FMA score < 50 at randomisation); being able to comply with requirements of the protocol Exclusion criteria: other significant upper limb impairment; diagnosis likely to interfere with rehabilitation or outcome assessments; participation in other stroke rehabilitation trial
Interventions	Experimental group: robotic therapy using InMotion device plus standard care for up to 12 1-hourly sessions Control group: rehabilitation therapy according to local guidelines
Outcomes	Primary outcomes will be collected at 1-month follow-up, and secondary outcomes will be collected at 3-month follow-up Primary outcomes: 1. FMA 2. feasibility

NCT01552733 *(Continued)*

	Secondary outcomes: 1. FMA 2. Modified Rankin Scale score 3. BI 4. SIS 5. NIHSS 6. ARAT
Starting date	March 2012
Contact information	Jesse Dawson, MD; jesse.dawson@glasgow.ac.uk
Notes	

NCT01655446

Trial name or title	Randomised trial of robotic rehabilitation, mirror therapy, and dose-matched control intervention for upper-limb rehabilitation in patients with chronic stroke: comparative efficacy and clinimetric study
Methods	RCT with factorial assignment
Participants	Country: Taiwan Participants: estimated enrolment n = 100 Inclusion criteria: unilateral stroke; onset more than 6 months; written informed consent; initial scores on the upper extremity FMA score of 25 to 56 or 18 to 50; MMSE ≥ 24 points; no upper limb fracture in the last 3 months Exclusion criteria: recurrent stroke or seizures during the intervention; serious or continuous pain on affected upper extremity; history of other neurological disease or severe orthopaedic condition
Interventions	Experimental group 1: robotic rehabilitation combined functional electrical stimulation (5 to 10 minutes of warm-up, 1 hour of robotic rehabilitation with combined functional electrical stimulation, and 15 to 20 minutes of functional-activities training 5 days a week for 4 weeks) Experimental group 2: mirror therapy (1 hour mirror therapy and 0.5 hour functional training per day, 5 days a week for 4 weeks); focuses on symmetrical bimanual movements and simultaneously observing the mirror visual feedback reflected by the unaffected upper extremity Experimental group 3: robotic rehabilitation (5 to 10 minutes of warm-up, 1 hour of robotic rehabilitation, and 15 to 20 minutes of functional-activities training 5 days a week for 4 weeks) Control group 1 (active): conventional rehabilitation (participants in this group received a structured protocol based on occupational therapy such as neurodevelopmental techniques and task-oriented approach for 1.5 hours per day, 5 days a week for 4 weeks) Control group 2 (placebo): like experimental group 1 but without any electrical current applied for 1.5 hours per day, 5 days a week for 4 weeks
Outcomes	Outcomes will be collected at baseline and at 4, 8, 16, and 28 weeks Primary outcomes: 1. FMA 2. MAS

NCT01655446 *(Continued)*

	3. FIM 4. movement smoothness (movement units) 5. trajectory smoothness (total displacement) 6. pre-motor planning ability (percentage of peak velocity) 7. speed of motor planning (reaction time) 8. ARAT 9. MRC 10. Muscle tone 11. amount of the impaired arm movement outside the laboratory (accelerometer) 12. produced force (peak velocity) 13. trunk-related kinematic variables Secondary outcomes: 1. MAL 2. ABILHAND questionnaire 3. SIS 3.0 4. Nottingham Extended Activities of Daily Living Scale 5. revised Nottingham Sensory Assessment 6. FMA Sensory 7. oxidative stress 8. Multidimensional Fatigue Symptom Inventory
Starting date	August 2011
Contact information	Keh-chung Lin, ScD; kehchunglin@ntu.edu.tw
Notes	

NCT01767480

Trial name or title	Effects and mechanisms of intensive robot-assisted therapy in patients with subacute stroke: outcomes in brain/movement reorganisation, sensorimotor and daily functions, and physiological markers
Methods	RCT
Participants	Country: Taiwan Participants: estimated enrolment n = 90 Inclusion criteria: age between 20 and 75 years; first-ever unilateral stroke; time since stroke < 3 months; initial motor part of upper limb FMA score ranging from 10 to 40; MMSE score > 23 Exclusion criteria: pregnant or breastfeeding; aphasia interfering with understanding of instructions; major health problems or poor physical condition; current participation in other research; contraindications to fMRI
Interventions	Experimental group 1 (higher-intensity robotic training group; 1200 to 1800 repetitions during robot-assisted functional rehabilitation with the Bi-Manu-Track device): 90 to 120 minutes per day for 5 days a week for 4 consecutive weeks Experimental group 2 (lower-intensity robotic training group; 600 to 900 repetitions during robot-assisted functional rehabilitation with the Bi-Manu-Track device): 90 to 120 minutes per day for 5 days a week for 4 consecutive weeks

NCT01767480 *(Continued)*

	Control group (active): neurodevelopmental techniques with emphasis on functional tasks
Outcomes	Outcomes will be measured at baseline and at the end of study Primary outcomes: 1. FMA 2. Motor Status Scale 3. MAS 4. Muscle tone 5. Muscle metabolism (near-infrared spectroscopy) 6. BBT 7. Revised Nottingham Sensory Assessment 8. FIM 9. MAL 10.ABILHAND questionnaire 11.Adelaide Activites Profile 12.EQ-5D-5L 13.accelerometers 14.fMRI 15.kinematic analysis 16.inflammatory markers 17.oxidative stress markers 18.erythrocyte deformability 19.blood glucose indicators
Starting date	January 2013
Contact information	Ching-Yi Wu, ScD; cywu@mail.cgu.edu.tw
Notes	

NCT01907139

Trial name or title	Comparative efficacy research of robot-assisted therapy with and without constraint-induced therapy in stroke rehabilitation: does the combined therapy improve outcomes compared with monotherapy?
Methods	RCT with factorial assignment
Participants	Country: Taiwan Participants: estimated enrolment n = 80 Inclusion criteria: aged between 20 to 80 years; unilateral first-ever stroke; 6 months from onset; initial upper extremity FMA score of 20 to 56; minimal motor criteria to receive constraint-induced therapy (i.e. ≥ 100 wrist extension and ≥ 100 extension at the thumb and any other 2 digits); MAS ≤ 3 of the affected upper extremity; no upper limb fracture within the last 3 months; MMSE ≥ 24 points; written informed consent Exclusion criteria: major medical problems or poor physical condition that would interfere with participation; excessive pain in any joint that might limit participation

NCT01907139 *(Continued)*

Interventions	Experimental group 1: distributed constraint-induced therapy (placement of the hand in a mitt for 6 hours/day and intensive training of the affected upper limb in functional tasks for 1.5 hours/weekday over 4 weeks) Control group (active): dose-matched control therapy for 1.5 hours/weekday over 4 weeks Experimental group 2: robot-assisted therapy (ArmeoSpring) for 1.5 hours/weekday over 4 weeks Experimental group 3: robot-assisted therapy (ArmeoSpring) for 1.5 hours/weekday over 2 weeks plus distributed constraint-induced therapy for 1.5 hours/weekday over 2 weeks
Outcomes	Outcomes will be collected at baseline and at 2 and 4 weeks Primary outcomes: 1. FMA 2. WMFT 3. FIM 4. MAL 5. SIS 3.0 Secondary outcomes: 1. MRC 2. MAS 3. Revised Nottingham Sensory Assessment 4. muscle tone 5. activity (actigraphy) 6. visual analogue scale for assessing postexertional fatigue and pain 7. urinary 8-hydroxydeoxyguanosine 8. kinematic analysis
Starting date	August 2013
Contact information	Keh-chung Lin, ScD; School of Occupational Therapy, College of Medicine, National Taiwan University, Taiwan Yi-shiung Horng, PhD; Buddhist Tzu Chi General Hospital Taipei Branch
Notes	

NCT01939041

Trial name or title	Efficacy of unilateral versus bilateral approach to robot-assisted rehabilitation on motor control/performance, daily functions, and physiological responses in patients with subacute stroke
Methods	RCT
Participants	Country: Taiwan Participants: estimated enrolment n = 84 Inclusion criteria: first stroke; time since stroke less than 6 months and more than 2 weeks; initial motor impairment between 24 to 52 points on the upper extremity FMA; MMSE score ≥ 24 points Exclusion criteria: aphasia that might limit ability to understand instructions; chronic inflammatory, autoimmune, or haematological disorders; intake of anti-inflammatory drugs; major health

NCT01939041 *(Continued)*

	problems or poor physical condition that might interfere with participation; current enrolment in other research
Interventions	Experimental group 1: robot-assisted therapy with InMotion3 for 90 minutes per day, 5 days a week for 4 weeks Experimental group 2: robot-assisted therapy with Bi-Manu-Track for 90 minutes per day, 5 days a week for 4 weeks Control group (active): control intervention for 90 minutes per day, 5 days a week for 4 weeks
Outcomes	Outcomes will be collected at baseline, at study end, and at 6-month follow-up Primary outcomes: 1. change of kinematic analysis 2. FMA 3. MAS 4. muscle tone 5. MRC 6. grip strength (Jamar dynamometer) 7. ARAT 8. MAL 9. ABILHAND questionnaire 10.Accelerometer 11.Adelaide Activities Profile Secondary outcomes: 1. inflammatory markers 2. oxidative stress markers 3. erythrocyte deformability 4. blood glucose indicators
Starting date	August 2013
Contact information	Ching-Yi Wu, ScD; cywu@mail.cgu.edu.tw Chia-Ling Chen, PhD, MD; clingchen@gmail.com
Notes	

NCT02077439

Trial name or title	Interactive intention-driven upper-limb training robotic system
Methods	RCT
Participants	Country: China Participants: estimated enrolment n = 70 Inclusion criteria: age above 18 years; pure unilateral motor paresis after ischaemic or haemorrhagic stroke; sufficient cognition to understand instructions; being able to sit upright for 1 hour Exclusion criteria: excessive spasticity of the affected arm; involvement in any other therapy

NCT02077439 *(Continued)*

Interventions	Experimental group 1: hand robotic training for 20 1-hourly sessions, 3 to 5 times per week Experimental group 2: hand and arm robotic training for 20 1-hourly sessions, 3 to 5 times per week Control therapy (active): conventional therapy for 20 1-hourly sessions, 3 to 5 times per week
Outcomes	Outcomes will be measured at baseline, at the end of study, and at 3- and 6-months follow-up Primary outcomes: 1. FMA 2. ARAT Secondary outcomes: 1. WMFT 2. MAS
Starting date	January 2014
Contact information	Raymond KY Tong, PhD; k.y.tong@polyu.edu.hk
Notes	

NCT02079779

Trial name or title	Efficacy study of an interactive robot for the rehabilitation of the upper limb in acute stroke patients
Methods	RCT
Participants	Country: Belgium Inclusion criteria: 1. first stroke 2. acute stroke (less than 1 month) 3. unilateral localisation of the stroke 4. moderate to severe upper limb impairments (7 < FMA score < 50/66) Exclusion criteria: 1. brainstem or cerebellum stroke 2. an unstable clinical condition contraindicating the upper limb rehabilitation treatments 3. cognitive disorders preventing understanding of the instructions 4. other neurological or orthopaedic pathology affecting the upper limb
Interventions	2 groups: 1. robotic-assisted therapy 2. classical therapy
Outcomes	Outcomes were recorded at baseline and post-treatment every 2 weeks 1. kinematic 2. FMA 3. Stroke Impairment Assessment Set 4. BBT

NCT02079779 *(Continued)*

	5. MRC 6. MAS 7. Bells Test 8. WMFT 9. ABILHAND 10.ACTIVLIM 11.SIS
Starting date	Not described
Contact information	Thierry Lejeune, Professor: thierry.lejeune@uclouvain.be
Notes	

NCT02096445

Trial name or title	Neurocognitive robot-assisted rehabilitation of hand function after stroke
Methods	RCT
Participants	Country: Switzerland Participants: estimated enrolment n = 20 Inclusion criteria: aged between 18 and 90 years; first stroke with resulting hemiparesis; time since stroke less than 6 weeks Exclusion criteria: insufficient state of consciousness; severe aphasia; severe cognitive deficits; severe pathologies of the upper extremity of traumatic or rheumatic nature; severe pain in the affected arm; people with metal implants
Interventions	Experimental group: robot-assisted neurocognitive therapy (ReHapticKnob) for 45 minutes 4 times per week Control group: conventional neurocognitive therapy (Perfetti) for 45 minutes 4 times per week
Outcomes	Outcomes will be collected at baseline, at 4 and 8 weeks, and at 6 months Primary outcomes: 1. FMA Secondary outcomes: 1. FMA 2. BBT 3. MAS 4. tactile and proprioceptive sensory function of the upper limb (Erasmus Medical Center Nottingham Sensory Assessment) 5. neglect (Albert's test of neglect) 6. cognitive impairment (MMSE) 7. frontal lobe function (Frontal Assessment Battery) 8. aphasia (Aachen Aphasia Test) 9. attention
Starting date	April 2013

NCT02096445 *(Continued)*

Contact information	Daria Dinacci, MD; d.dinacci@clinica-hildebrand.ch
Notes	

NCT02188628

Trial name or title	Refinement and clinical evaluation of the H-Man: a novel, portable, inexpensive planar robot for arm rehabilitation after stroke
Methods	RCT
Participants	Country: Singapore Participants: estimated enrolment n = 60 Inclusion criteria: age between 21 and 85 years; first-ever clinical stroke confirmed by imaging; time since stroke between 3 and 24 months; hemiplegic pattern of motor impairment with MRC motor power of shoulder and elbow flexion grade ≥ 3; FMA score of the affected upper limb between 20 and 50 points; motor incoordination or motor ataxia Exclusion criteria: other causes of arm motor impairment; severe medical conditions; palliative care; severe arm pain; inability to sit for 90 minutes; local fractures; spasticity of MAS grades 3 to 4; skin wounds; shoulder pain > 5/10 visual analogue scale; severe sensory impairment of affected limb; severe visual impairment; hemispatial neglect or homonymous hemianopia; cognitive impairments or uncontrolled behaviour; MMSE < 26/28
Interventions	Experimental group: H-Man (end-effector upper limb robot; dosage not stated) Control group: additional conventional therapy (repetitive goals-based arm therapy; dosage not stated)
Outcomes	Outcomes will be collected at baseline and at 3, 6, 12, and 24 weeks after start of the intervention Primary outcomes: 1. FMA Secondary outcomes: 1. ARAT
Starting date	July 2014
Contact information	Chua SG Sui Geok; karen_chua@ttsh.com.sg
Notes	

NCT02228863

Trial name or title	Upper extremity rehabilitation using robot and botulinum toxin
Methods	RCT
Participants	Country: Republic of Korea Participants: estimated enrolment n = 348

NCT02228863 *(Continued)*

	Inclusion criteria: first-ever stroke; shoulder or elbow flexor spasticity ≥ MAS 1+; being able to follow instructions from the investigator Exclusion criteria: history of surgery or fracture of affected upper limb; Botox injection within the last 6 months
Interventions	Experimental group: early InMotion and Botox (robotic rehabilitation with the InMotion device and Botox for 8 weeks; dosage not stated) Control group 1: Botox, then InMotion (robotic rehabilitation 4 weeks after botulinum toxin injection; dosage not stated) Control group 2: InMotion, then Botox (robotic rehabilitation from the baseline, then Botox injection at 4 weeks after baseline; dosage not stated) Control group 3: late Inmotion and Botox (no intervention, then robotic rehabilitation and Botox injection at 4 weeks after baseline; dosage not stated)
Outcomes	Outcomes will be collected at baseline and 4, 8, and 12 weeks from baseline Primary outcomes: 1. FMA Secondary outcomes: 1. kinematic data (InMotion) 2. spasticity of elbow and shoulder joint (Modified Tardieu Scale) 3. MRC of elbow and shoulder joint strength 4. painless range of motion of elbow and shoulder joint 5. numeric rating scale of pain of elbow and shoulder joint 6. associated reaction rating scale 7. surface electromyography data from bilateral upper extremities 8. behavioural activation system/behavioural inhibition system scale 9. Controlled Oral Word Association Test 10.FMA 11.SIS 12.Beck Depression Inventory 13.satisfaction about the intervention 14.adverse events 15.digit span test
Starting date	March 2014
Contact information	Joon-Ho Shin, MS; asfreelyas@gmail.com
Notes	

NCT02254343

Trial name or title	Effects of proximal and distal robot-assisted therapy combined with functional training on stroke rehabilitation
Methods	RCT
Participants	Country: Taiwan

NCT02254343 *(Continued)*

	Participants: estimated enrolment n = 92 Inclusion criteria: unilateral stroke, radiologically confirmed; time since onset more than 6 months; upper extremity FMA score between 10 and 50; MMSE score > 24 points; being able to follow commands Exclusion criteria: serious visual or visual perception problems; orthopaedic or other neurological problems in the last 6 months prior to enrolment; participation in other studies in the last 3 months
Interventions	Experimental group 1: proximal robot-assisted therapy (InMotion2 device); dosage not described Experimental group 2: distal robot-assisted therapy (InMotion3 device); dosage not described Experimental group 3: combined robot-assisted therapy (InMotion2 and InMotion3 devices); dosage not described Control group (active): dose-matched, individualised intensive therapy; dosage not described
Outcomes	Outcomes will be collected at baseline, 2 weeks, and 4 weeks Primary outcomes: 1. FMA Secondary outcomes: 1. BBT 2. ARAT 3. MRC 4. MAS 5. muscle tone 6. WMFT 7. Chedoke Arm and Hand Activity Inventory 8. FIM 9. SIS 3.0 10.EuroQol Quality of Life Scale (EQ-5D) 11.hand strength 12.MAL 13.ABILHAND questionnaire 14.10-meter walking test 15.Nottingham Extended ADL Questionnaire 16.Adelaide Activities Profile 17.Montreal Cognitive Assessment 18.Number Stroop test 19.accelerometer 20.Revised Nottingham Sensory Assessment 21.algometer 22.kinematic analysis 23.adverse effects
Starting date	September 2014
Contact information	Ching-Yi Wu, ScD; cywu@mail.cgu.edu.tw
Notes	

NCT02319785

Trial name or title	Effects of robot-assisted combined therapy in upper limb rehabilitation in stroke patients
Methods	Randomised cross-over trial
Participants	Country: Taiwan Participants: estimated enrolment n = 120 Inclusion criteria: age 18 to 80 years; first-ever unilateral stroke > 3 months after onset; upper extremity FMA score between 18 to 56 points; no excessive spasticity in the affected upper extremity; being able to follow study instructions and to perform study tasks; written informed consent Exclusion criteria: neural or psychological problems that may interfere with study; severe joint pain; upper limb fracture within the last 3 months; participation in any other research
Interventions	Experimental group 1: robot-assisted therapy and neuromuscular electrical stimulation for 1.5 hours per day, 5 days a week for 4 weeks Experimental group 2: robot-assisted therapy and mirror therapy for 1.5 hours per day, 5 days a week for 4 weeks Experimental group 3: mirror therapy for 1.5 hours per day, 5 days a week for 4 weeks Experimental group 4: unilateral robot-assisted therapy (InMotion device) for 1.5 hours per day, 5 days a week for 4 weeks Experimental group 5: bilateral robot-assisted therapy (Bi-Manu-Track) for 1.5 hours per day, 5 days a week for 4 weeks Control group (active): conventional rehabilitation for 1.5 hours per day, 5 days a week for 4 weeks
Outcomes	Outcomes will be collected at baseline and at the end of study at 4 weeks Primary outcomes: 1. kinematic analyses 2. FMA Secondary outcomes: 1. 10-meter walk test 2. WMFT 3. FIM 4. ARAT Other outcome measures: 1. MRC 2. Functional Ambulation Categories 3. MAS 4. MAL 5. ABILHAND questionnaire 6. SIS 3.0
Starting date	August 2014
Contact information	Keh-Chung Lin; kehchunglin@ntu.edu.tw Chung-Shan Hung; f00429003@ntu.edu.tw

NCT02319785 *(Continued)*

Notes	

NCT02323061

Trial name or title	Brain Computer Interface (BCI) system for stroke rehabilitation
Methods	RCT
Participants	Country: China Participants: estimated enrolment n = 60 Inclusion criteria: age above 18 years; hemiparesis resulting from a single unilateral lesion of the brain; at least 6 months after onset; subcortical ischaemic lesion within the territory of the middle cerebral artery; being able to follow simple instructions; understand purpose and content of the experiment; moderate to severe motor disability in the paretic upper limb Exclusion criteria: severe hand spasticity; open hand wound or hand deformity; visual-field defects; aphasia; neglect; apraxia; participation in any therapeutic treatment outside the study; history of substance abuse; bilateral infarctions; uncontrolled medical problems; serious cognitive deficits; other MRI contraindications
Interventions	Experimental group 1: EEG-guided robotic training based on ipsilesional EEG signals for 30 sessions Experimental group 2: EEG-guided training based on both ipsilesional and contralesional EEG signals for 30 sessions Control group: placebo comparator robot for 30 sessions
Outcomes	Outcomes will be collected at 3-month follow-up Primary outcomes: 1. FMA Secondary outcomes: 1. ARAT 2. MAS 3. MRI
Starting date	May 2015
Contact information	Raymond Tong, PhD; +852 3943 8454
Notes	

NTR3669

Trial name or title	Feasibility of supervised care and rehabilitation involving personal telerobotics for arm/hand function of chronic stroke patients
Methods	RCT
Participants	Country: the Netherlands

NTR3669 *(Continued)*

	Participants: estimated enrolment n = 20 Inclusion criteria: age between 18 and 80 years; unilateral and ischaemic or haemorrhagic stroke; time since stroke between 6 and 12 months; clinical diagnosis of central paresis of arm or hand with 15° active elbow flexion; 1/4 range of active finger flexion; ability to complete measurements and training sessions; discharged from medical centre; living at home and having Internet access; having a carer who is co-resident or closely involved in care; ability to read, understand, and follow instructions; device fits to the person; written informed consent Exclusion criteria: receiving additional therapy to the affected upper extremity during the study; not eligible to join normal rehabilitation; other severe comorbidities; severe sensory impairments; severe neglect; visual impairments; cognitive impairment
Interventions	Experimental group: 60 minutes of technology-assisted arm/hand training for 18 sessions during 6 weeks (consisting of computerised gaming wearing the SCRIPT hand device to support hand opening and the SaeboMAS for gravity compensation) Control group: 60 minutes of technology-assisted arm/hand training for 18 sessions during 6 weeks of conventional home training (standard arm and hand exercises)
Outcomes	Primary outcomes: 1. user acceptance (usability, satisfaction, motivation, compliance) Secondary outcomes: 1. ARAT 2. FMA 3. BBT 4. MAL 5. SIS 6. kinematics 7. EMG
Starting date	January 2013
Contact information	Sharon Nijenhuis, MSc; s.nijenhuis@rrd.nl
Notes	

RATULS

Trial name or title	Robot Assisted Training for the Upper Limb after Stroke (RATULS)
Methods	Multicentre RCT
Participants	Country: UK Inclusion criteria: adults with acute or chronic stroke causing moderate to severe upper limb functional limitation
Interventions	3 groups: 1. robot-assisted training using the InMotion robotic gym system 2. enhanced upper limb therapy 3. usual care

RATULS *(Continued)*

Outcomes	Primary outcome: upper limb function measured by ARAT at 3 months' post randomisation Secondary outcomes: upper limb impairment, activities of daily living, quality of life, resource use, and adverse events measured at 3 and 6 months' post randomisation
Starting date	April 2014
Contact information	https://research.ncl.ac.uk/ratuls/contact%20us/
Notes	Sample size: 720 participants Study duration: 57 months

ABILHAND: a measure of manual ability for people with upper limb impairments
ACTIVLIM: a measure of activity limitations for people with upper and/or lower limb impairments
ADL: activities of daily living
ARAT: Action Research Arm Test
BBT: Box and Block Test
BCI: Brain computer Interface
BI: Barthel Index
Bi-Manu-Track:
BOLD: blood oxygenation level dependent
CT: computerised tomography
EEG: electroencephalogram
EMG: electromyography
EQ-5D-5L: five level version of the EQ-%D a generic instrument for describing and valuing health
FIM: Functional Independence Measure
FMA: Fugl-Meyer Assessment
fMRI: functional magnetic resonance imaging
H-Man: is the name of an end-effector upper limb robot
MAL: Motor Activity Log
MAS: Modified Ashworth Scale
MMSE: Mini-Mental State Examination
MRC: Medical Research Council
MRI: magnetic resonance imaging
NIHSS: National Institutes of Health Stroke Scale
NTUH: National Taiwan University Hospital
RCT: randomised controlled trial
SaeboMAS: mini mobile arm support
SCRIPT: a hand device to support hand opening
SIS: Stroke Impact Scale
UE: upper extremity
WMFT: Wolf Motor Function Test

DATA AND ANALYSES

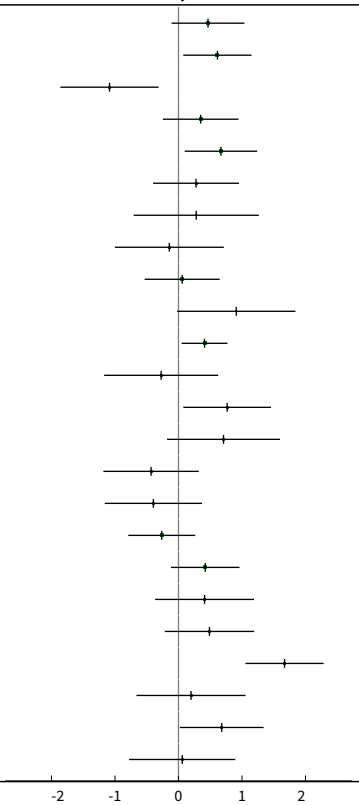
Comparison 1. Electromechanical and robotic assisted training versus all other intervention

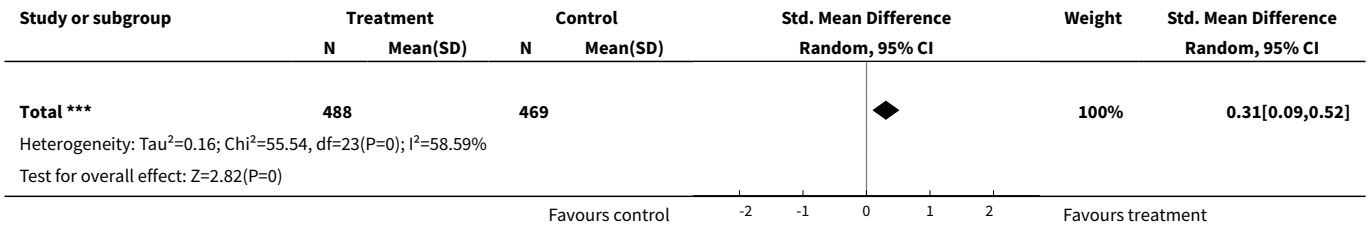
Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Activities of daily living at the end of intervention phase	24	957	Std. Mean Difference (IV, Random, 95% CI)	0.31 [0.09, 0.52]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
2 Activities of daily living at the end of intervention phase: subgroup analysis comparing acute and chronic phase	24		Std. Mean Difference (IV, Random, 95% CI)	Subtotals only
2.1 Participants treated in the acute and subacute phase of their stroke (within 3 months)	13	532	Std. Mean Difference (IV, Random, 95% CI)	0.40 [0.10, 0.70]
2.2 Participants treated in the chronic phase (more than 3 months)	11	425	Std. Mean Difference (IV, Random, 95% CI)	0.19 [-0.13, 0.50]
3 Arm function at the end of intervention phase	41	1452	Std. Mean Difference (IV, Random, 95% CI)	0.32 [0.18, 0.46]
4 Arm muscle strength at the end of intervention phase	23	826	Std. Mean Difference (IV, Random, 95% CI)	0.46 [0.16, 0.77]
5 Acceptability: dropouts during intervention period	45	1619	Risk Difference (M-H, Random, 95% CI)	-0.00 [-0.02, 0.02]

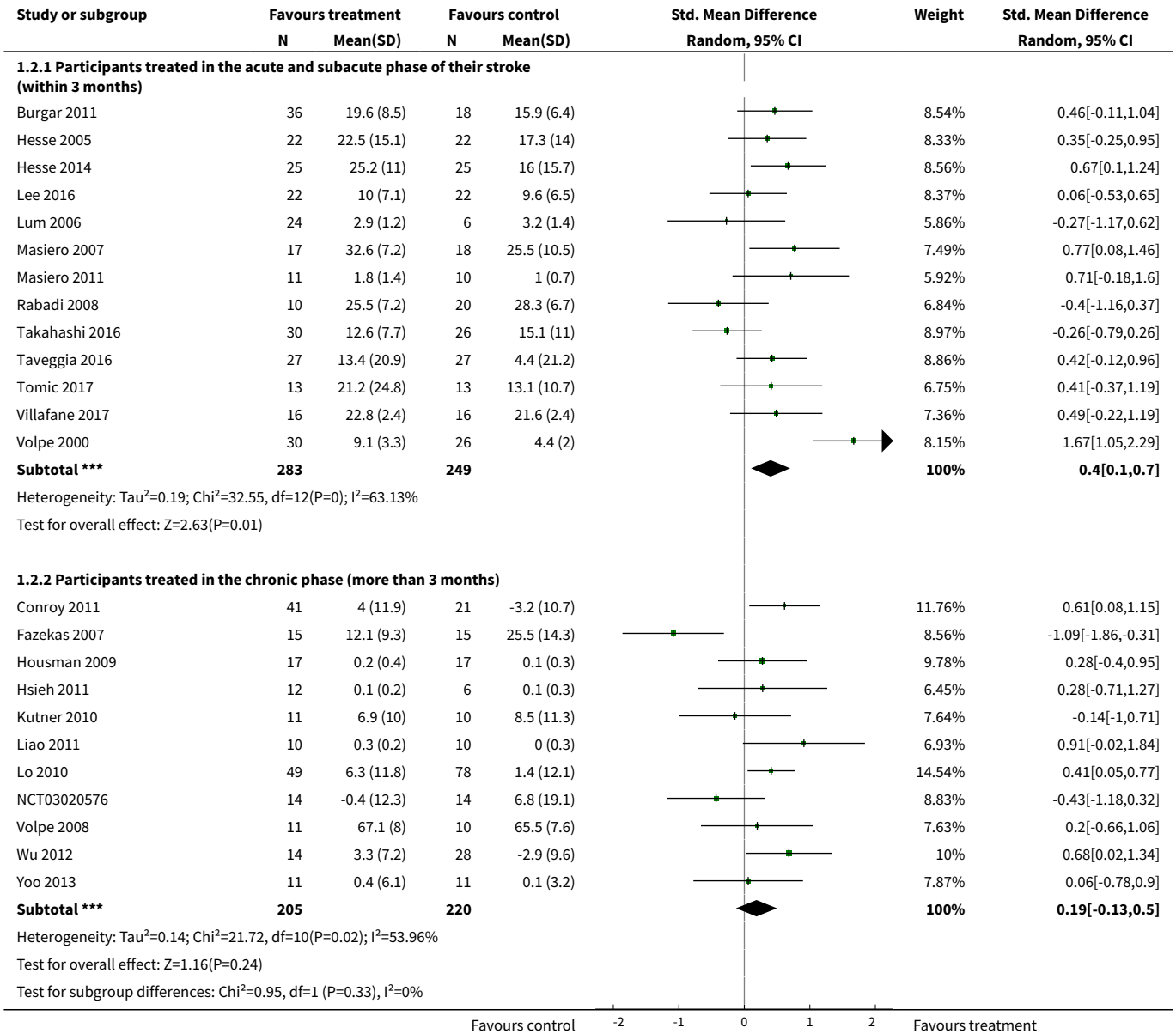
Analysis 1.1. Comparison 1 Electromechanical and robotic assisted training versus all other intervention, Outcome 1 Activities of daily living at the end of intervention phase.

Study or subgroup	Treatment N	Treatment Mean(SD)	Control N	Control Mean(SD)	Std. Mean Difference Random, 95% CI	Weight	Std. Mean Difference Random, 95% CI
Burgar 2011	36	19.6 (8.5)	18	15.9 (6.4)		4.86%	0.46[-0.11,1.04]
Conroy 2011	41	4 (11.9)	21	-3.2 (10.7)		5.07%	0.61[0.08,1.15]
Fazekas 2007	15	12.1 (9.3)	15	25.5 (14.3)		3.76%	-1.09[-1.86,-0.31]
Hesse 2005	22	22.5 (15.1)	22	17.3 (14)		4.72%	0.35[-0.25,0.95]
Hesse 2014	25	25.2 (11)	25	16 (15.7)		4.87%	0.67[0.1,1.24]
Housman 2009	17	0.2 (0.4)	17	0.1 (0.3)		4.27%	0.28[-0.4,0.95]
Hsieh 2011	12	0.1 (0.2)	6	0.1 (0.3)		2.88%	0.28[-0.71,1.27]
Kutner 2010	11	6.9 (10)	10	8.5 (11.3)		3.38%	-0.14[-1,0.71]
Lee 2016	22	10 (7.1)	22	9.6 (6.5)		4.75%	0.06[-0.53,0.65]
Liao 2011	10	0.3 (0.2)	10	0 (0.3)		3.08%	0.91[-0.02,1.84]
Lo 2010	49	6.3 (11.8)	78	1.4 (12.1)		6.16%	0.41[0.05,0.77]
Lum 2006	24	2.9 (1.2)	6	3.2 (1.4)		3.21%	-0.27[-1.17,0.62]
Masiero 2007	17	32.6 (7.2)	18	25.5 (10.5)		4.19%	0.77[0.08,1.46]
Masiero 2011	11	1.8 (1.4)	10	1 (0.7)		3.25%	0.71[-0.18,1.6]
NCT03020576	14	-0.4 (12.3)	14	6.8 (19.1)		3.88%	-0.43[-1.18,0.32]
Rabadi 2008	10	25.5 (7.2)	20	28.3 (6.7)		3.8%	-0.4[-1.16,0.37]
Takahashi 2016	30	12.6 (7.7)	26	15.1 (11)		5.13%	-0.26[-0.79,0.26]
Taveggia 2016	27	13.4 (20.9)	27	4.4 (21.2)		5.06%	0.42[-0.12,0.96]
Tomic 2017	13	21.2 (24.8)	13	13.1 (10.7)		3.74%	0.41[-0.37,1.19]
Villafane 2017	16	22.8 (2.4)	16	21.6 (2.4)		4.12%	0.49[-0.22,1.19]
Volpe 2000	30	9.1 (3.3)	26	4.4 (2)		4.61%	1.67[1.05,2.29]
Volpe 2008	11	67.1 (8)	10	65.5 (7.6)		3.38%	0.2[-0.66,1.06]
Wu 2012	14	3.3 (7.2)	28	-2.9 (9.6)		4.36%	0.68[0.02,1.34]
Yoo 2013	11	0.4 (6.1)	11	0.1 (3.2)		3.48%	0.06[-0.78,0.9]





Analysis 1.2. Comparison 1 Electromechanical and robotic assisted training versus all other intervention, Outcome 2 Activities of daily living at the end of intervention phase: subgroup analysis comparing acute and chronic phase.

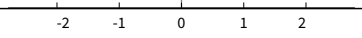


Analysis 1.3. Comparison 1 Electromechanical and robotic assisted training versus all other intervention, Outcome 3 Arm function at the end of intervention phase.

Study or subgroup	Treatment		Control		Std. Mean Difference	Weight	Std. Mean Difference
	N	Mean(SD)	N	Mean(SD)	Random, 95% CI		Random, 95% CI
Abdullah 2011	9	2.8 (1.8)	11	1 (1.7)		1.69%	0.96[0.02,1.91]
Ang 2014	15	7.3 (3.5)	7	4.9 (4.1)		1.76%	0.63[-0.29,1.55]
Brokaw 2014	7	1.8 (2)	5	1.2 (2)		1.22%	0.28[-0.88,1.43]
Burgar 2011	36	10.6 (11.6)	18	14 (15.3)		3.33%	-0.26[-0.83,0.31]
Bustamante 2016	10	4.6 (3.9)	10	5.1 (4.7)		1.89%	-0.11[-0.99,0.77]
Conroy 2011	41	2.3 (3.4)	21	1.2 (3.4)		3.59%	0.33[-0.2,0.86]
Daly 2005	7	8.2 (7.3)	6	9.5 (8)		1.34%	-0.16[-1.25,0.93]
Fazekas 2007	15	5.5 (1.4)	15	2.6 (1.8)		1.92%	1.8[0.93,2.66]
Grigoras 2016	13	3.2 (0.9)	12	3.5 (0.8)		2.2%	-0.31[-1.1,0.48]
Hesse 2005	22	20.5 (19.9)	22	2.8 (5)		2.86%	1.2[0.55,1.85]
Hesse 2014	25	11.1 (10.6)	25	14.6 (11.2)		3.39%	-0.32[-0.87,0.24]
Hollenstein 2011	7	3.4 (3.9)	6	3.7 (4.1)		1.34%	-0.07[-1.16,1.02]
Housman 2009	17	3.3 (2.4)	17	2.2 (2.6)		2.68%	0.43[-0.25,1.11]
Hsieh 2011	12	4.2 (5.9)	6	2.8 (7.4)		1.59%	0.2[-0.78,1.18]
Hsieh 2014	32	7.3 (5.5)	16	3.8 (5)		3.04%	0.64[0.03,1.26]
Hwang 2012	9	3.5 (4.2)	6	1.3 (4.3)		1.42%	0.49[-0.56,1.54]
Klamroth-Marganska 2014	39	3.3 (1.7)	38	2.5 (1.7)		4.16%	0.46[0.01,0.91]
Kutner 2010	11	26.5 (17.5)	10	14.9 (19.9)		1.88%	0.6[-0.28,1.48]
Lee 2016	22	1.6 (1.5)	22	1.2 (1.8)		3.17%	0.24[-0.35,0.83]
Liao 2011	10	6.3 (5.6)	10	1.3 (7.9)		1.79%	0.7[-0.21,1.61]
Lo 2010	49	3.9 (7.4)	78	-0 (6.4)		4.93%	0.57[0.21,0.94]
Lum 2006	24	7 (1.8)	6	6.5 (2.5)		1.83%	0.24[-0.66,1.14]
Masiero 2007	17	15.8 (8.1)	18	10.3 (12.1)		2.71%	0.52[-0.16,1.19]
Masiero 2011	11	12.2 (8.3)	10	13.9 (10.2)		1.95%	-0.18[-1.04,0.68]
Mayr 2008	4	3 (2.9)	4	1.3 (1.3)		0.81%	0.67[-0.79,2.13]
McCabe 2015	12	7.7 (3.8)	27	9.4 (4.9)		2.66%	-0.35[-1.04,0.33]
NCT03020576	14	2.1 (16.3)	14	5.9 (13.7)		2.39%	-0.25[-0.99,0.5]
Orihuela-Espina 2016	9	5.7 (2.7)	8	1.5 (2.3)		1.27%	1.57[0.44,2.69]
Rabadi 2008	10	3.1 (8.1)	20	3.9 (6.9)		2.32%	-0.11[-0.87,0.65]
Sale 2014	26	8.7 (7.5)	27	3.6 (10.7)		3.45%	0.53[-0.02,1.08]
Susanto 2015	9	5.1 (6.6)	10	5.7 (4.4)		1.81%	-0.1[-1,0.8]
Takahashi 2016	30	9.5 (7.9)	26	6.9 (8.8)		3.59%	0.31[-0.22,0.84]
Timmermans 2014	11	1.6 (10.8)	11	3.5 (32.7)		2.03%	-0.08[-0.91,0.76]
Tomic 2017	13	26.5 (7.7)	13	26.6 (7.5)		2.28%	-0.01[-0.78,0.76]
Vanoglio 2017	14	15.7 (19)	13	0.4 (7.5)		2.12%	1.01[0.2,1.82]
Villafane 2017	16	9.9 (1.9)	16	9.1 (1.9)		2.58%	0.41[-0.29,1.11]
Volpe 2000	30	6 (3.5)	26	4 (2)		3.51%	0.68[0.14,1.22]
Volpe 2008	11	19.5 (13.3)	10	17.7 (8.2)		1.95%	0.15[-0.71,1.01]
Wolf 2015	51	10.3 (7.3)	48	9.4 (8.9)		4.66%	0.12[-0.28,0.51]
Wu 2012	14	3.9 (6.7)	28	3.7 (7.1)		2.89%	0.02[-0.62,0.66]
Yoo 2013	11	1.7 (9.9)	11	0.3 (3.9)		2.02%	0.18[-0.66,1.02]
Total ***	**745**		**707**			**100%**	**0.32[0.18,0.46]**

Heterogeneity: Tau^2=0.07; Chi^2=62.11, df=40(P=0.01); I^2=35.6%

Test for overall effect: Z=4.45(P<0.0001)



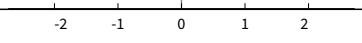
Favours control — Favours treatment

Analysis 1.4. Comparison 1 Electromechanical and robotic assisted training versus all other intervention, Outcome 4 Arm muscle strength at the end of intervention phase.

Study or subgroup	Treatment N	Treatment Mean(SD)	Control N	Control Mean(SD)	Std. Mean Difference Random, 95% CI	Weight	Std. Mean Difference Random, 95% CI
Burgar 2011	36	14.9 (11.2)	18	15.4 (15.7)		5.03%	-0.04[-0.61,0.52]
Hesse 2005	22	12.1 (8.4)	22	4.3 (6.2)		4.82%	1.05[0.41,1.68]
Hesse 2014	25	7.5 (7.1)	25	8.1 (6.4)		5.06%	-0.09[-0.64,0.47]
Housman 2009	17	0.8 (3)	17	0.8 (2.3)		4.7%	0[-0.67,0.67]
Hsieh 2011	12	3.5 (0.5)	6	3.3 (0.7)		3.73%	0.33[-0.66,1.31]
Hwang 2012	9	1.7 (7)	6	1.3 (6.3)		3.6%	0.06[-0.98,1.09]
Klamroth-Marganska 2014	39	1.4 (8)	38	2.6 (9.5)		5.37%	-0.14[-0.58,0.31]
Lee 2016	22	0.3 (0.5)	22	0.2 (0.4)		4.94%	0.26[-0.33,0.85]
Lum 2006	24	7.9 (7.5)	6	9.3 (3.2)		4%	-0.2[-1.1,0.69]
Masiero 2007	17	1.7 (1.2)	18	1.2 (1)		4.7%	0.46[-0.21,1.13]
Masiero 2011	11	0.8 (0.6)	10	1.5 (0.9)		3.95%	-0.94[-1.85,-0.03]
Mayr 2008	4	3.6 (4.4)	4	2.4 (4.2)		2.69%	0.25[-1.14,1.65]
NCT03020576	14	0.8 (5.3)	14	1.6 (7.8)		4.48%	-0.12[-0.86,0.63]
Orihuela-Espina 2016	9	12 (7.8)	8	5.3 (6.6)		3.66%	0.88[-0.13,1.89]
Rabadi 2008	10	8.3 (7.9)	20	1.2 (9.6)		4.34%	0.76[-0.02,1.55]
Sale 2014	26	13.9 (15.5)	27	9.3 (21.7)		5.1%	0.24[-0.3,0.78]
Takahashi 2016	30	6.5 (11)	26	8.4 (13.7)		5.14%	-0.15[-0.67,0.38]
Taveggia 2016	27	17.7 (20.8)	27	11.4 (16)		5.11%	0.33[-0.2,0.87]
Vanoglio 2017	14	23 (17.9)	13	5.2 (10.2)		4.21%	1.17[0.34,2]
Villafane 2017	16	24.4 (2.6)	16	14.9 (2.6)		3.25%	3.56[2.4,4.72]
Volpe 2000	30	4.1 (1.4)	26	1.7 (1.7)		4.92%	1.53[0.93,2.13]
Volpe 2008	11	4.8 (0.7)	10	3.4 (0.3)		3.07%	2.64[1.41,3.87]
Yoo 2013	11	1 (3.6)	11	0.1 (1.5)		4.16%	0.31[-0.53,1.16]
Total ***	**436**		**390**			**100%**	**0.46[0.16,0.77]**

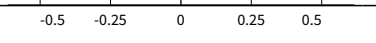
Heterogeneity: Tau²=0.41; Chi²=92.55, df=22(P<0.0001); I²=76.23%

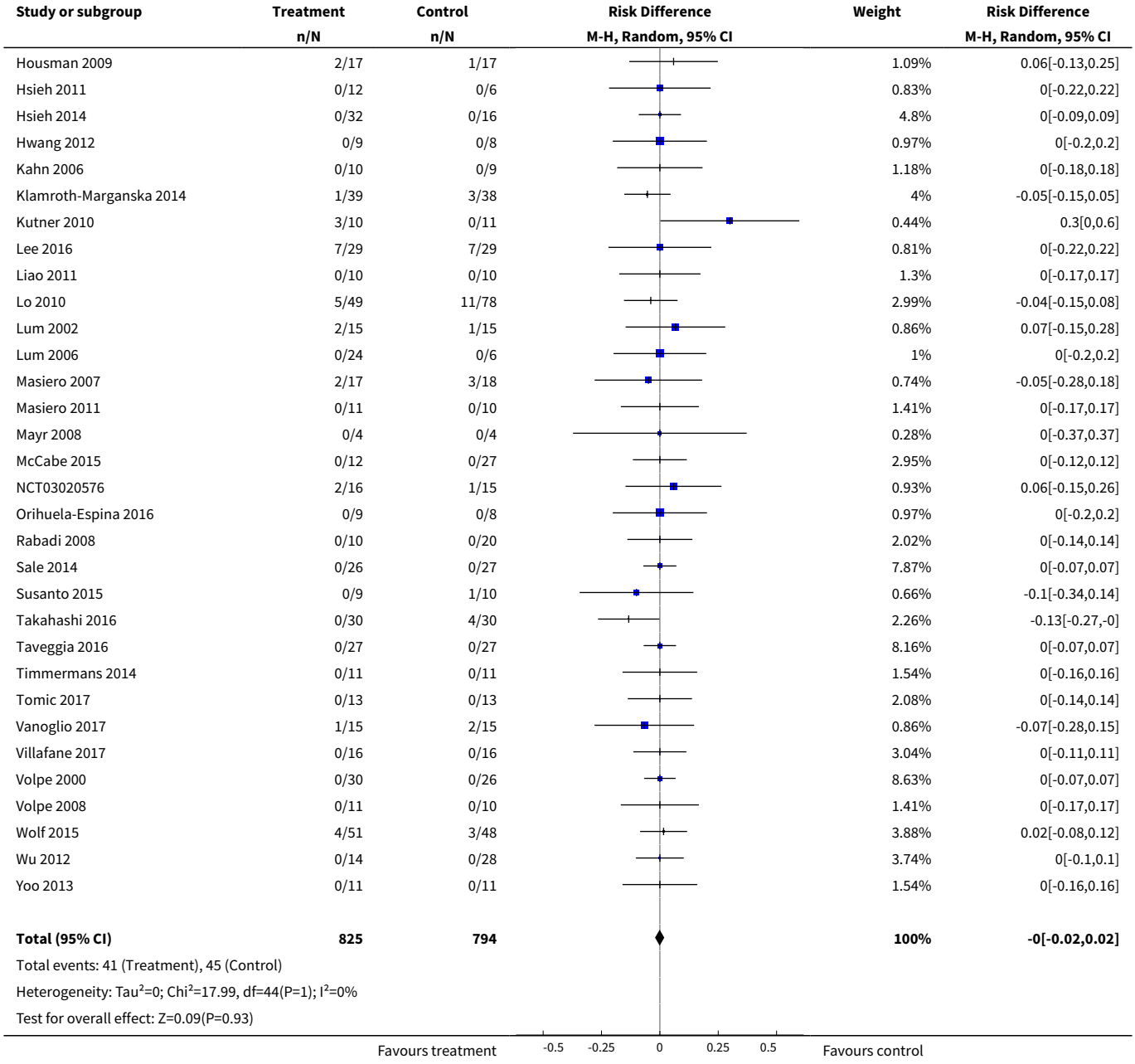
Test for overall effect: Z=2.95(P=0)



Analysis 1.5. Comparison 1 Electromechanical and robotic assisted training versus all other intervention, Outcome 5 Acceptability: dropouts during intervention period.

Study or subgroup	Treatment n/N	Control n/N	Risk Difference M-H, Random, 95% CI	Weight	Risk Difference M-H, Random, 95% CI
Abdullah 2011	1/9	0/11		0.64%	0.11[-0.14,0.36]
Amirabdollahian 2007	0/16	0/15		2.86%	0[-0.12,0.12]
Ang 2014	0/15	0/7		1.11%	0[-0.19,0.19]
Brokaw 2014	0/7	2/5		0.21%	-0.4[-0.83,0.03]
Burgar 2011	0/36	0/18		5.98%	0[-0.08,0.08]
Bustamante 2016	3/13	4/14		0.36%	-0.05[-0.38,0.27]
Conroy 2011	5/41	2/21		1.52%	0.03[-0.13,0.19]
Daly 2005	1/7	0/6		0.36%	0.14[-0.19,0.47]
Fazekas 2007	0/15	0/15		2.7%	0[-0.12,0.12]
Grigoras 2016	0/13	0/12		1.93%	0[-0.14,0.14]
Hesse 2005	1/22	0/22		2.86%	0.05[-0.07,0.16]
Hesse 2014	1/25	0/25		3.63%	0.04[-0.06,0.14]
Hollenstein 2011	0/7	0/6		0.61%	0[-0.25,0.25]





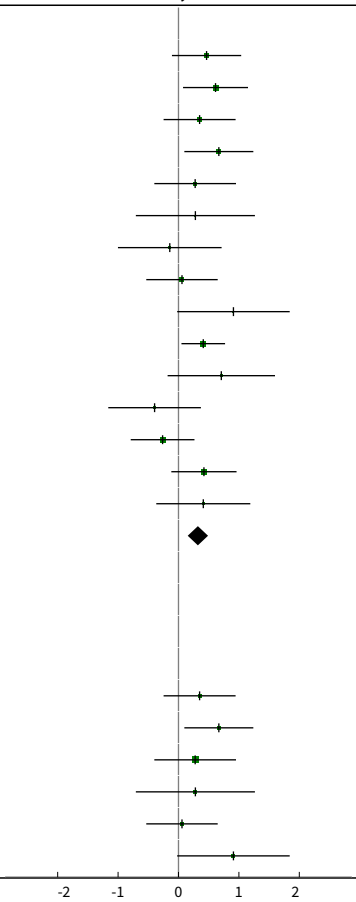
Comparison 2. Sensitivity analysis: by trial methodology

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Activities of daily living	21		Std. Mean Difference (IV, Random, 95% CI)	Subtotals only
1.1 All studies with description of randomisation procedure	15	661	Std. Mean Difference (IV, Random, 95% CI)	0.32 [0.15, 0.49]

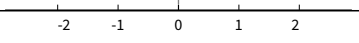
Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1.2 All studies with adequate concealed allocation	10	392	Std. Mean Difference (IV, Random, 95% CI)	0.28 [0.03, 0.52]
1.3 All studies with blinded assessors	20	808	Std. Mean Difference (IV, Random, 95% CI)	0.29 [0.10, 0.49]
2 Arm function	37		Std. Mean Difference (IV, Random, 95% CI)	Subtotals only
2.1 All studies with description of randomisation procedure	28	1048	Std. Mean Difference (IV, Random, 95% CI)	0.32 [0.16, 0.47]
2.2 All studies with adequate concealed allocation	12	462	Std. Mean Difference (IV, Random, 95% CI)	0.43 [0.21, 0.64]
2.3 All studies with blinded assessors	32	1220	Std. Mean Difference (IV, Random, 95% CI)	0.33 [0.18, 0.49]

Analysis 2.1. Comparison 2 Sensitivity analysis: by trial methodology, Outcome 1 Activities of daily living.

Study or subgroup	Treatment N	Treatment Mean(SD)	Control N	Control Mean(SD)	Std. Mean Difference Random, 95% CI	Weight	Std. Mean Difference Random, 95% CI
2.1.1 All studies with description of randomisation procedure							
Burgar 2011	36	19.6 (8.5)	18	15.9 (6.4)		7.68%	0.46[-0.11,1.04]
Conroy 2011	41	4 (11.9)	21	-3.2 (10.7)		8.6%	0.61[0.08,1.15]
Hesse 2005	22	22.5 (15.1)	22	17.3 (14)		7.16%	0.35[-0.25,0.95]
Hesse 2014	25	25.2 (11)	25	16 (15.7)		7.73%	0.67[0.1,1.24]
Housman 2009	17	0.2 (0.4)	17	0.1 (0.3)		5.69%	0.28[-0.4,0.95]
Hsieh 2011	12	0.1 (0.2)	6	0.1 (0.3)		2.8%	0.28[-0.71,1.27]
Kutner 2010	11	6.9 (10)	10	8.5 (11.3)		3.65%	-0.14[-1,0.71]
Lee 2016	22	10 (7.1)	22	9.6 (6.5)		7.26%	0.06[-0.53,0.65]
Liao 2011	10	0.3 (0.2)	10	0 (0.3)		3.12%	0.91[-0.02,1.84]
Lo 2010	49	6.3 (11.8)	78	1.4 (12.1)		16.61%	0.41[0.05,0.77]
Masiero 2011	11	1.8 (1.4)	10	1 (0.7)		3.41%	0.71[-0.18,1.6]
Rabadi 2008	10	25.5 (7.2)	20	28.3 (6.7)		4.51%	-0.4[-1.16,0.37]
Takahashi 2016	30	12.6 (7.7)	26	15.1 (11)		8.88%	-0.26[-0.79,0.26]
Taveggia 2016	27	13.4 (20.9)	27	4.4 (21.2)		8.54%	0.42[-0.12,0.96]
Tomic 2017	13	21.2 (24.8)	13	13.1 (10.7)		4.38%	0.41[-0.37,1.19]
Subtotal ***	**336**		**325**			**100%**	**0.32[0.15,0.49]**
Heterogeneity: Tau^2=0.01; Chi^2=15.47, df=14(P=0.35); I^2=9.48%							
Test for overall effect: Z=3.74(P=0)							
2.1.2 All studies with adequate concealed allocation							
Hesse 2005	22	22.5 (15.1)	22	17.3 (14)		11.42%	0.35[-0.25,0.95]
Hesse 2014	25	25.2 (11)	25	16 (15.7)		12.08%	0.67[0.1,1.24]
Housman 2009	17	0.2 (0.4)	17	0.1 (0.3)		9.6%	0.28[-0.4,0.95]
Hsieh 2011	12	0.1 (0.2)	6	0.1 (0.3)		5.31%	0.28[-0.71,1.27]
Lee 2016	22	10 (7.1)	22	9.6 (6.5)		11.55%	0.06[-0.53,0.65]
Liao 2011	10	0.3 (0.2)	10	0 (0.3)		5.83%	0.91[-0.02,1.84]



Study or subgroup	Treatment N	Treatment Mean(SD)	Control N	Control Mean(SD)	Std. Mean Difference Random, 95% CI	Weight	Std. Mean Difference Random, 95% CI
Rabadi 2008	10	25.5 (7.2)	20	28.3 (6.7)		7.96%	-0.4[-1.16,0.37]
Takahashi 2016	30	12.6 (7.7)	26	15.1 (11)		13.34%	-0.26[-0.79,0.26]
Taveggia 2016	27	13.4 (20.9)	27	4.4 (21.2)		12.97%	0.42[-0.12,0.96]
Wu 2012	14	3.3 (7.2)	28	-2.9 (9.6)		9.94%	0.68[0.02,1.34]
Subtotal * **	**189**		**203**			**100%**	**0.28[0.03,0.52]**
Heterogeneity: Tau^2=0.05; Chi^2=12.85, df=9(P=0.17); I^2=29.96%							
Test for overall effect: Z=2.2(P=0.03)							
2.1.3 All studies with blinded assessors							
Burgar 2011	36	19.6 (8.5)	18	15.9 (6.4)		6.09%	0.46[-0.11,1.04]
Conroy 2011	41	4 (11.9)	21	-3.2 (10.7)		6.49%	0.61[0.08,1.15]
Fazekas 2007	15	12.1 (9.3)	15	25.5 (14.3)		4.25%	-1.09[-1.86,-0.31]
Hesse 2005	22	22.5 (15.1)	22	17.3 (14)		5.84%	0.35[-0.25,0.95]
Hesse 2014	25	25.2 (11)	25	16 (15.7)		6.11%	0.67[0.1,1.24]
Housman 2009	17	0.2 (0.4)	17	0.1 (0.3)		5.05%	0.28[-0.4,0.95]
Hsieh 2011	12	0.1 (0.2)	6	0.1 (0.3)		3%	0.28[-0.71,1.27]
Kutner 2010	11	6.9 (10)	10	8.5 (11.3)		3.69%	-0.14[-1,0.71]
Liao 2011	10	0.3 (0.2)	10	0 (0.3)		3.27%	0.91[-0.02,1.84]
Lo 2010	49	6.3 (11.8)	78	1.4 (12.1)		8.9%	0.41[0.05,0.77]
Lum 2006	24	2.9 (1.2)	6	3.2 (1.4)		3.45%	-0.27[-1.17,0.62]
Masiero 2007	17	32.6 (7.2)	18	25.5 (10.5)		4.93%	0.77[0.08,1.46]
Masiero 2011	11	1.8 (1.4)	10	1 (0.7)		3.5%	0.71[-0.18,1.6]
Rabadi 2008	10	25.5 (7.2)	20	28.3 (6.7)		4.3%	-0.4[-1.16,0.37]
Takahashi 2016	30	12.6 (7.7)	26	15.1 (11)		6.61%	-0.26[-0.79,0.26]
Taveggia 2016	27	13.4 (20.9)	27	4.4 (21.2)		6.47%	0.42[-0.12,0.96]
Tomic 2017	13	21.2 (24.8)	13	13.1 (10.7)		4.22%	0.41[-0.37,1.19]
Villafane 2017	16	22.8 (2.4)	16	21.6 (2.4)		4.8%	0.49[-0.22,1.19]
Wu 2012	14	3.3 (7.2)	28	-2.9 (9.6)		5.2%	0.68[0.02,1.34]
Yoo 2013	11	0.4 (6.1)	11	0.1 (3.2)		3.82%	0.06[-0.78,0.9]
Subtotal * **	**411**		**397**			**100%**	**0.29[0.1,0.49]**
Heterogeneity: Tau^2=0.08; Chi^2=32.4, df=19(P=0.03); I^2=41.35%							
Test for overall effect: Z=2.92(P=0)							
Test for subgroup differences: Chi^2=0.1, df=1 (P=0.95), I^2=0%							

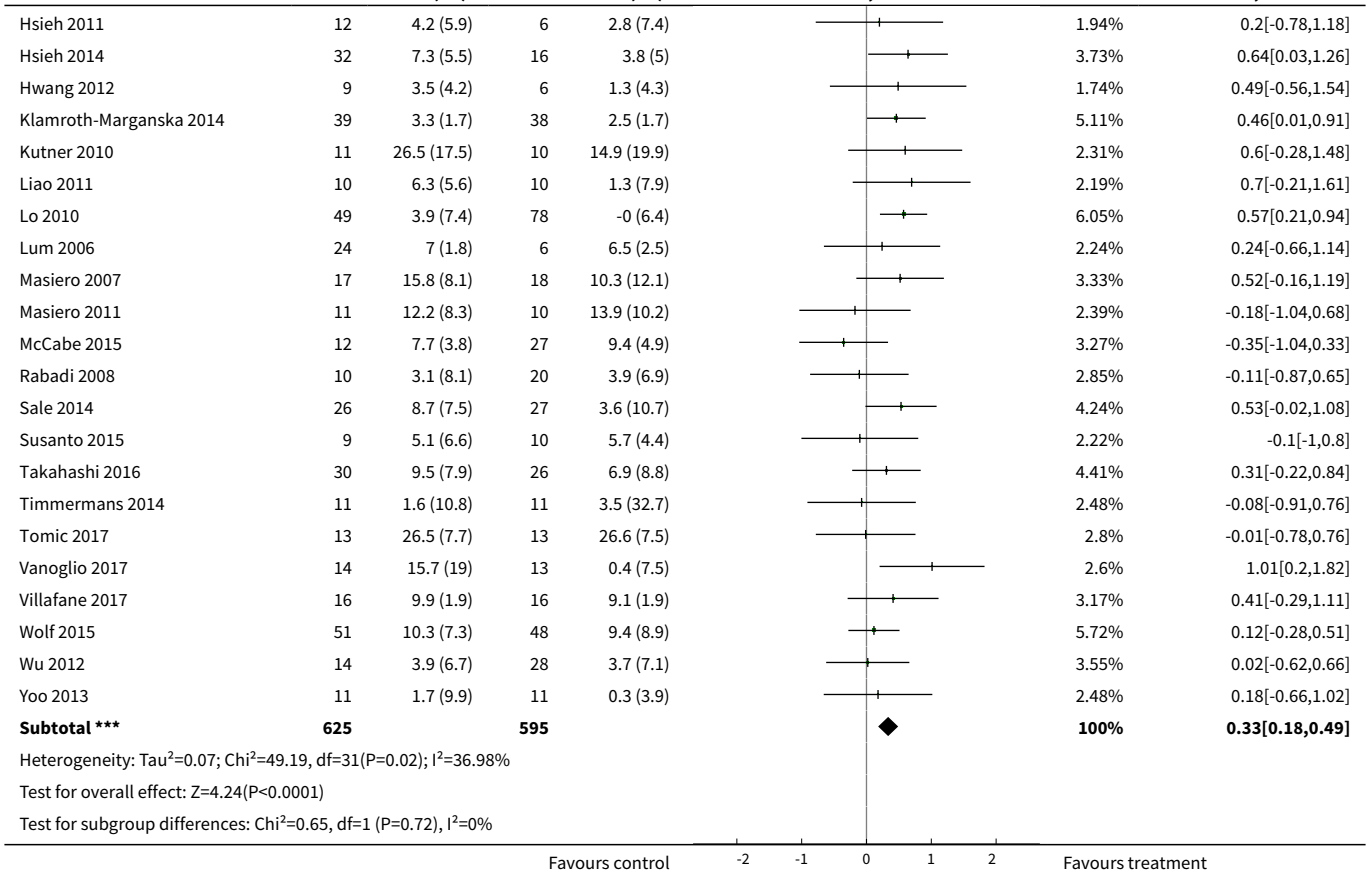


Analysis 2.2. Comparison 2 Sensitivity analysis: by trial methodology, Outcome 2 Arm function.

Study or subgroup	Treatment N	Treatment Mean(SD)	Control N	Control Mean(SD)	Std. Mean Difference Random, 95% CI	Weight	Std. Mean Difference Random, 95% CI
2.2.1 All studies with description of randomisation procedure							
Abdullah 2011	9	2.8 (1.8)	11	1 (1.7)		2.27%	0.96[0.02,1.91]
Ang 2014	15	7.3 (3.5)	7	4.9 (4.1)		2.36%	0.63[-0.29,1.55]
Brokaw 2014	7	1.8 (2)	5	1.2 (2)		1.6%	0.28[-0.88,1.43]
Burgar 2011	36	10.6 (11.6)	18	14 (15.3)		4.8%	-0.26[-0.83,0.31]
Bustamante 2016	10	4.6 (3.9)	10	5.1 (4.7)		2.55%	-0.11[-0.99,0.77]
Conroy 2011	41	2.3 (3.4)	21	1.2 (3.4)		5.25%	0.33[-0.2,0.86]
Hesse 2005	22	20.5 (19.9)	22	2.8 (5)		4.04%	1.2[0.55,1.85]
Hesse 2014	25	11.1 (10.6)	25	14.6 (11.2)		4.91%	-0.32[-0.87,0.24]
Hollenstein 2011	7	3.4 (3.9)	6	3.7 (4.1)		1.77%	-0.07[-1.16,1.02]

Study or subgroup	Treatment N	Treatment Mean(SD)	Control N	Control Mean(SD)	Std. Mean Difference Random, 95% CI	Weight	Std. Mean Difference Random, 95% CI
Housman 2009	17	3.3 (2.4)	17	2.2 (2.6)		3.75%	0.43[-0.25,1.11]
Hsieh 2011	12	4.2 (5.9)	6	2.8 (7.4)		2.11%	0.2[-0.78,1.18]
Hsieh 2014	32	7.3 (5.5)	16	3.8 (5)		4.33%	0.64[0.03,1.26]
Hwang 2012	9	3.5 (4.2)	6	1.3 (4.3)		1.88%	0.49[-0.56,1.54]
Klamroth-Marganska 2014	39	3.3 (1.7)	38	2.5 (1.7)		6.26%	0.46[0.01,0.91]
Kutner 2010	11	26.5 (17.5)	10	14.9 (19.9)		2.54%	0.6[-0.28,1.48]
Lee 2016	22	1.6 (1.5)	22	1.2 (1.8)		4.54%	0.24[-0.35,0.83]
Liao 2011	10	6.3 (5.6)	10	1.3 (7.9)		2.4%	0.7[-0.21,1.61]
Lo 2010	49	3.9 (7.4)	78	-0 (6.4)		7.7%	0.57[0.21,0.94]
Masiero 2011	11	12.2 (8.3)	10	13.9 (10.2)		2.64%	-0.18[-1.04,0.68]
Mayr 2008	4	3 (2.9)	4	1.3 (1.3)		1.05%	0.67[-0.79,2.13]
Orihuela-Espina 2016	9	5.7 (2.7)	8	1.5 (2.3)		1.67%	1.57[0.44,2.69]
Rabadi 2008	10	3.1 (8.1)	20	3.9 (6.9)		3.19%	-0.11[-0.87,0.65]
Susanto 2015	9	5.1 (6.6)	10	5.7 (4.4)		2.44%	-0.1[-1,0.8]
Takahashi 2016	30	9.5 (7.9)	26	6.9 (8.8)		5.26%	0.31[-0.22,0.84]
Timmermans 2014	11	1.6 (10.8)	11	3.5 (32.7)		2.75%	-0.08[-0.91,0.76]
Timmermans 2014	11	1.6 (10.8)	11	3.5 (32.7)		2.75%	-0.08[-0.91,0.76]
Tomic 2017	13	26.5 (7.7)	13	26.6 (7.5)		3.14%	-0.01[-0.78,0.76]
Vanoglio 2017	14	15.7 (19)	13	0.4 (7.5)		2.9%	1.01[0.2,1.82]
Wolf 2015	51	10.3 (7.3)	48	9.4 (8.9)		7.18%	0.12[-0.28,0.51]
Subtotal * **	**546**		**502**			**100%**	**0.32[0.16,0.47]**
Heterogeneity: Tau²=0.05; Chi²=38.94, df=28(P=0.08); I²=28.09%							
Test for overall effect: Z=4.02(P<0.0001)							
2.2.2 All studies with adequate concealed allocation							
Hesse 2005	22	20.5 (19.9)	22	2.8 (5)		8.81%	1.2[0.55,1.85]
Housman 2009	17	3.3 (2.4)	17	2.2 (2.6)		8.12%	0.43[-0.25,1.11]
Hsieh 2011	12	4.2 (5.9)	6	2.8 (7.4)		4.36%	0.2[-0.78,1.18]
Hsieh 2014	32	7.3 (5.5)	16	3.8 (5)		9.53%	0.64[0.03,1.26]
Klamroth-Marganska 2014	39	3.3 (1.7)	38	2.5 (1.7)		14.63%	0.46[0.01,0.91]
Lee 2016	22	1.6 (1.5)	22	1.2 (1.8)		10.05%	0.24[-0.35,0.83]
Liao 2011	10	6.3 (5.6)	10	1.3 (7.9)		5%	0.7[-0.21,1.61]
Rabadi 2008	10	3.1 (8.1)	20	3.9 (6.9)		6.8%	-0.11[-0.87,0.65]
Takahashi 2016	30	9.5 (7.9)	26	6.9 (8.8)		11.9%	0.31[-0.22,0.84]
Timmermans 2014	11	1.6 (10.8)	11	3.5 (32.7)		5.78%	-0.08[-0.91,0.76]
Vanoglio 2017	14	15.7 (19)	13	0.4 (7.5)		6.11%	1.01[0.2,1.82]
Wu 2012	14	3.9 (6.7)	28	3.7 (7.1)		8.92%	0.02[-0.62,0.66]
Subtotal * **	**233**		**229**			**100%**	**0.43[0.21,0.64]**
Heterogeneity: Tau²=0.03; Chi²=13.95, df=11(P=0.24); I²=21.13%							
Test for overall effect: Z=3.84(P=0)							
2.2.3 All studies with blinded assessors							
Abdullah 2011	9	2.8 (1.8)	11	1 (1.7)		2.08%	0.96[0.02,1.91]
Ang 2014	15	7.3 (3.5)	7	4.9 (4.1)		2.15%	0.63[-0.29,1.55]
Brokaw 2014	7	1.8 (2)	5	1.2 (2)		1.49%	0.28[-0.88,1.43]
Burgar 2011	36	10.6 (11.6)	18	14 (15.3)		4.08%	-0.26[-0.83,0.31]
Conroy 2011	41	2.3 (3.4)	21	1.2 (3.4)		4.41%	0.33[-0.2,0.86]
Daly 2005	7	8.2 (7.3)	6	9.5 (8)		1.64%	-0.16[-1.25,0.93]
Fazekas 2007	15	5.5 (1.4)	15	2.6 (1.8)		2.36%	1.8[0.93,2.66]
Hesse 2005	22	20.5 (19.9)	22	2.8 (5)		3.51%	1.2[0.55,1.85]
Hesse 2014	25	11.1 (10.6)	25	14.6 (11.2)		4.16%	-0.32[-0.87,0.24]
Housman 2009	17	3.3 (2.4)	17	2.2 (2.6)		3.29%	0.43[-0.25,1.11]

Favours control -2 -1 0 1 2 Favours treatment



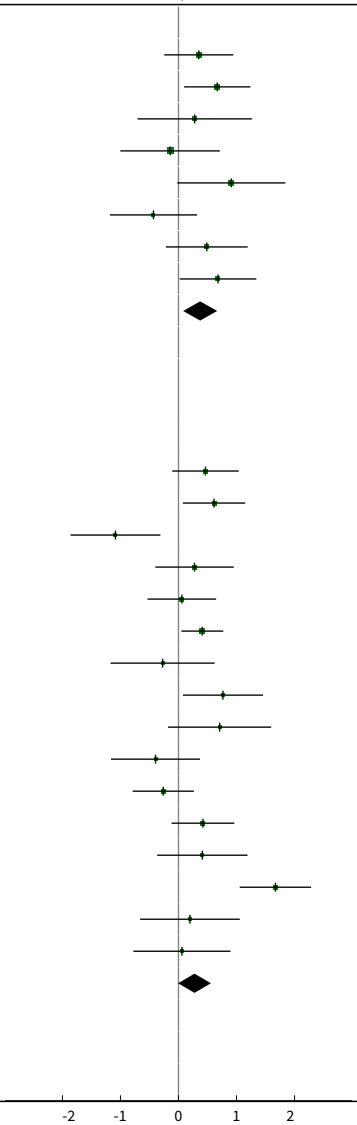
Comparison 3. Subgroup analysis by treatment approach

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Activities of daily living at the end of intervention phase: subgroup analysis comparing different device groups	24		Std. Mean Difference (IV, Random, 95% CI)	Subtotals only
1.1 Distal training (finger, hand and radio-ulnar joints)	8	255	Std. Mean Difference (IV, Random, 95% CI)	0.37 [0.08, 0.67]
1.2 Proximal training (shoulder and elbow joints)	16	702	Std. Mean Difference (IV, Random, 95% CI)	0.28 [-0.01, 0.56]
2 Arm function at the end of intervention phase: subgroup analysis comparing different device groups	41		Std. Mean Difference (IV, Random, 95% CI)	Subtotals only
2.1 Distal training (finger, hand and radio-ulnar joints)	17	547	Std. Mean Difference (IV, Random, 95% CI)	0.34 [0.09, 0.59]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
2.2 Proximal training (shoulder and elbow joints)	24	905	Std. Mean Difference (IV, Random, 95% CI)	0.31 [0.15, 0.48]

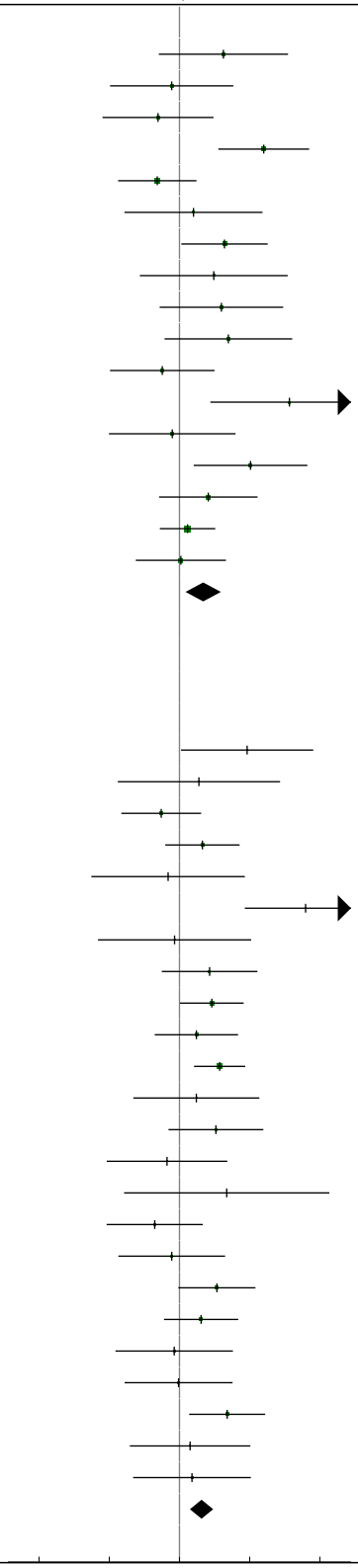
Analysis 3.1. Comparison 3 Subgroup analysis by treatment approach, Outcome 1 Activities of daily living at the end of intervention phase: subgroup analysis comparing different device groups.

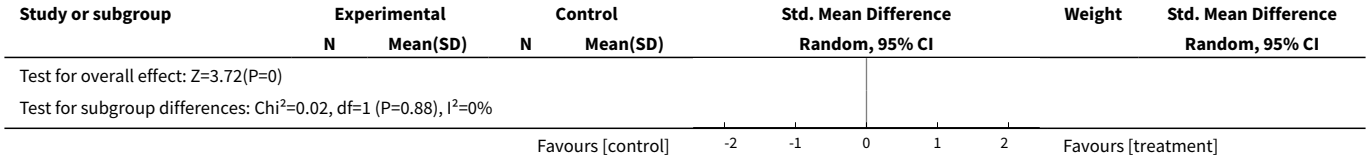
Study or subgroup	Experimental N	Experimental Mean(SD)	Control N	Control Mean(SD)	Std. Mean Difference Random, 95% CI	Weight	Std. Mean Difference Random, 95% CI
3.1.1 Distal training (finger, hand and radio-ulnar joints)							
Hesse 2005	22	22.5 (15.1)	22	17.3 (14)		16.82%	0.35[-0.25,0.95]
Hesse 2014	25	25.2 (11)	25	16 (15.7)		17.84%	0.67[0.1,1.24]
Hsieh 2011	12	0.1 (0.2)	6	0.1 (0.3)		7.63%	0.28[-0.71,1.27]
Kutner 2010	11	6.9 (10)	10	8.5 (11.3)		9.64%	-0.14[-1,0.71]
Liao 2011	10	0.3 (0.2)	10	0 (0.3)		8.4%	0.91[-0.02,1.84]
NCT03020576	14	-0.4 (12.3)	14	6.8 (19.1)		11.95%	-0.43[-1.18,0.32]
Villafane 2017	16	22.8 (2.4)	16	21.6 (2.4)		13.18%	0.49[-0.22,1.19]
Wu 2012	14	3.3 (7.2)	28	-2.9 (9.6)		14.55%	0.68[0.02,1.34]
Subtotal ***	**124**		**131**			**100%**	**0.37[0.08,0.67]**
Heterogeneity: Tau^2=0.04; Chi^2=9.08, df=7(P=0.25); I^2=22.91%							
Test for overall effect: Z=2.5(P=0.01)							
3.1.2 Proximal training (shoulder and elbow joints)							
Burgar 2011	36	19.6 (8.5)	18	15.9 (6.4)		6.94%	0.46[-0.11,1.04]
Conroy 2011	41	4 (11.9)	21	-3.2 (10.7)		7.19%	0.61[0.08,1.15]
Fazekas 2007	15	12.1 (9.3)	15	25.5 (14.3)		5.63%	-1.09[-1.86,-0.31]
Housman 2009	17	0.2 (0.4)	17	0.1 (0.3)		6.25%	0.28[-0.4,0.95]
Lee 2016	22	10 (7.1)	22	9.6 (6.5)		6.82%	0.06[-0.53,0.65]
Lo 2010	49	6.3 (11.8)	78	1.4 (12.1)		8.38%	0.41[0.05,0.77]
Lum 2006	24	2.9 (1.2)	6	3.2 (1.4)		4.91%	-0.27[-1.17,0.62]
Masiero 2007	17	32.6 (7.2)	18	25.5 (10.5)		6.16%	0.77[0.08,1.46]
Masiero 2011	11	1.8 (1.4)	10	1 (0.7)		4.96%	0.71[-0.18,1.6]
Rabadi 2008	10	25.5 (7.2)	20	28.3 (6.7)		5.67%	-0.4[-1.16,0.37]
Takahashi 2016	30	12.6 (7.7)	26	15.1 (11)		7.26%	-0.26[-0.79,0.26]
Taveggia 2016	27	13.4 (20.9)	27	4.4 (21.2)		7.18%	0.42[-0.12,0.96]
Tomic 2017	13	21.2 (24.8)	13	13.1 (10.7)		5.6%	0.41[-0.37,1.19]
Volpe 2000	30	9.1 (3.3)	26	4.4 (2)		6.66%	1.67[1.05,2.29]
Volpe 2008	11	67.1 (8)	10	65.5 (7.6)		5.13%	0.2[-0.66,1.06]
Yoo 2013	11	0.4 (6.1)	11	0.1 (3.2)		5.26%	0.06[-0.78,0.9]
Subtotal ***	**364**		**338**			**100%**	**0.28[-0.01,0.56]**
Heterogeneity: Tau^2=0.22; Chi^2=46.26, df=15(P<0.0001); I^2=67.58%							
Test for overall effect: Z=1.91(P=0.06)							
Test for subgroup differences: Chi^2=0.22, df=1 (P=0.64), I^2=0%							



Analysis 3.2. Comparison 3 Subgroup analysis by treatment approach, Outcome 2 Arm function at the end of intervention phase: subgroup analysis comparing different device groups.

Study or subgroup	Experimental N	Experimental Mean(SD)	Control N	Control Mean(SD)	Std. Mean Difference Random, 95% CI	Weight	Std. Mean Difference Random, 95% CI
3.2.1 Distal training (finger, hand and radio-ulnar joints)							
Ang 2014	15	7.3 (3.5)	7	4.9 (4.1)		4.77%	0.63[-0.29,1.55]
Bustamante 2016	10	4.6 (3.9)	10	5.1 (4.7)		5.06%	-0.11[-0.99,0.77]
Grigoras 2016	13	3.2 (0.9)	12	3.5 (0.8)		5.73%	-0.31[-1.1,0.48]
Hesse 2005	22	20.5 (19.9)	22	2.8 (5)		7.04%	1.2[0.55,1.85]
Hesse 2014	25	11.1 (10.6)	25	14.6 (11.2)		7.99%	-0.32[-0.87,0.24]
Hsieh 2011	12	4.2 (5.9)	6	2.8 (7.4)		4.38%	0.2[-0.78,1.18]
Hsieh 2014	32	7.3 (5.5)	16	3.8 (5)		7.37%	0.64[0.03,1.26]
Hwang 2012	9	3.5 (4.2)	6	1.3 (4.3)		3.99%	0.49[-0.56,1.54]
Kutner 2010	11	26.5 (17.5)	10	14.9 (19.9)		5.05%	0.6[-0.28,1.48]
Liao 2011	10	6.3 (5.6)	10	1.3 (7.9)		4.85%	0.7[-0.21,1.61]
NCT03020576	14	2.1 (16.3)	14	5.9 (13.7)		6.12%	-0.25[-0.99,0.5]
Orihuela-Espina 2016	9	5.7 (2.7)	8	1.5 (2.3)		3.62%	1.57[0.44,2.69]
Susanto 2015	9	5.1 (6.6)	10	5.7 (4.4)		4.9%	-0.1[-1,0.8]
Vanoglio 2017	14	15.7 (19)	13	0.4 (7.5)		5.57%	1.01[0.2,1.82]
Villafane 2017	16	9.9 (1.9)	16	9.1 (1.9)		6.51%	0.41[-0.29,1.11]
Wolf 2015	51	10.3 (7.3)	48	9.4 (8.9)		9.95%	0.12[-0.28,0.51]
Wu 2012	14	3.9 (6.7)	28	3.7 (7.1)		7.1%	0.02[-0.62,0.66]
Subtotal ***	**286**		**261**			**100%**	**0.34[0.09,0.59]**
Heterogeneity: Tau²=0.13; Chi²=30.54, df=16(P=0.02); I²=47.6%							
Test for overall effect: Z=2.63(P=0.01)							
3.2.2 Proximal training (shoulder and elbow joints)							
Abdullah 2011	9	2.8 (1.8)	11	1 (1.7)		2.61%	0.96[0.02,1.91]
Brokaw 2014	7	1.8 (2)	5	1.2 (2)		1.83%	0.28[-0.88,1.43]
Burgar 2011	36	10.6 (11.6)	18	14 (15.3)		5.62%	-0.26[-0.83,0.31]
Conroy 2011	41	2.3 (3.4)	21	1.2 (3.4)		6.15%	0.33[-0.2,0.86]
Daly 2005	7	8.2 (7.3)	6	9.5 (8)		2.02%	-0.16[-1.25,0.93]
Fazekas 2007	15	5.5 (1.4)	15	2.6 (1.8)		3%	1.8[0.93,2.66]
Hollenstein 2011	7	3.4 (3.9)	6	3.7 (4.1)		2.02%	-0.07[-1.16,1.02]
Housman 2009	17	3.3 (2.4)	17	2.2 (2.6)		4.36%	0.43[-0.25,1.11]
Klamroth-Marganska 2014	39	3.3 (1.7)	38	2.5 (1.7)		7.4%	0.46[0.01,0.91]
Lee 2016	22	1.6 (1.5)	22	1.2 (1.8)		5.3%	0.24[-0.35,0.83]
Lo 2010	49	3.9 (7.4)	78	-0 (6.4)		9.19%	0.57[0.21,0.94]
Lum 2006	24	7 (1.8)	6	6.5 (2.5)		2.83%	0.24[-0.66,1.14]
Masiero 2007	17	15.8 (8.1)	18	10.3 (12.1)		4.41%	0.52[-0.16,1.19]
Masiero 2011	11	12.2 (8.3)	10	13.9 (10.2)		3.04%	-0.18[-1.04,0.68]
Mayr 2008	4	3 (2.9)	4	1.3 (1.3)		1.19%	0.67[-0.79,2.13]
McCabe 2015	12	7.7 (3.8)	27	9.4 (4.9)		4.32%	-0.35[-1.04,0.33]
Rabadi 2008	10	3.1 (8.1)	20	3.9 (6.9)		3.69%	-0.11[-0.87,0.65]
Sale 2014	26	8.7 (7.5)	27	3.6 (10.7)		5.88%	0.53[-0.02,1.08]
Takahashi 2016	30	9.5 (7.9)	26	6.9 (8.8)		6.16%	0.31[-0.22,0.84]
Timmermans 2014	11	1.6 (10.8)	11	3.5 (32.7)		3.17%	-0.08[-0.91,0.76]
Tomic 2017	13	26.5 (7.7)	13	26.6 (7.5)		3.63%	-0.01[-0.78,0.76]
Volpe 2000	30	6 (3.5)	26	4 (2)		5.98%	0.68[0.14,1.22]
Volpe 2008	11	19.5 (13.3)	10	17.7 (8.2)		3.04%	0.15[-0.71,1.01]
Yoo 2013	11	1.7 (9.9)	11	0.3 (3.9)		3.16%	0.18[-0.66,1.02]
Subtotal ***	**459**		**446**			**100%**	**0.31[0.15,0.48]**
Heterogeneity: Tau²=0.04; Chi²=31.46, df=23(P=0.11); I²=26.9%							





ADDITIONAL TABLES

Table 1. Participant characteristics in studies

Study ID	Age, mean (SD) EXP	Age, mean (SD) CON	Time post-stroke EXP	Time post-stroke CON	Gender EXP	Gender CON	Side-paresis EXP	Side-paresis CON	Stroke severity	Aetiology (ischaemic/haemorrhagic)
Abdullah 2011	76 (6) years	70 (16) years	4 (2) weeks	4 (2) weeks	3 F, 5 M	8 F, 3 M	3 L, 5 R	6 L, 4 R, 1 both	Stage 1-3 CMSA	Not stated
Amirabdollahian 2007	67 (7) years	68 (9) years	17 (12) months	31 (22) months	9 F, 7 M	5 F, 10 M	9 L, 7 R	7 L, 8 R	Not stated	Not stated
Ang 2014	52 (7) years	58 (19) years	350 (131) days	455 (110) days	4 F, 10 M	3 F, 4 M	Not stated	Not stated	Mean 27 points FMA upper extremity	11/10
Brokaw 2014	57 (12) years		3 (2) years		3 F, 9 M		7 L, 5 R		Mean 22 points FMA upper extremity	Not stated
Burgar 2011	60 (2) years*	68 (3) years*	17 (3) days*	11 (1) days*	Not stated	Not stated	18 L, 18 R	5 L, 13 R	Mean 27 points FIM upper limb	Not stated
Bustamante 2016	44 (13) years	64 (8) years	not described, but inclusion criteria says a minimum of 6 months post stroke		7 F, 3 M	6 F, 4 M	Not stated	Not stated	Mean 23 points FMA upper extremity	Not stated
Conroy 2011	59 (13) years	56 (6) years	4 (5) years	4 (6) years	23 F, 18 M	11 F, 10 M	Not stated	Not stated	Mean 72 points score on SIS, ADL	51/6
Daly 2005	Not stated	Not stated	> 12 months	> 12 months	0 F, 6 M	3 F, 3 M	Not stated	Not stated	Not stated	11/1
Fazekas 2007	57 years	56 years	23 months	10 months	8 F, 7 M	5 F, 10 M	7 L, 8 R	6 L, 9 R	Mean 30 points FIM self-care	Not stated: also included people after head trauma
Grigoras 2016	63 (9) years	65 (11) years	4 (1) months	4 (1) months	5 F, 8 M	6 F, 6 M	0 L, 12 R	0 L, 12 R	Mean 19 points FMA upper extremity	23/2
Hesse 2005	65 (12) years	64 (12) years	5 (1) weeks	5 (1) weeks	12 F, 10 M	12 F, 10 M	14 L, 8 R	11 L, 11 R	Mean 42 of 100 Barthel points	40/4

Table 1. Participant characteristics in studies *(Continued)*

Hesse 2014	71 (16) years	70 (17) years	5 (2) weeks	5 (1) weeks	12 F, 13 M	10 F, 15 M	14 L, 11 R	13 L, 12 R	Mean 27 of 100 Barthel points	41/9
Hollenstein 2011	71 (8) years	75 (11) years	33 (14) days	29 (10) days	4 F, 3 M	5 F, 1 M	4 L, 3 R	3 L, 3 R	Not stated	Not stated
Housman 2009	54 (12) years	56 (11) years	> 12 months	> 12 months	3 F, 11 M	7 F, 7 M	10 L, 4 R	10 L, 4 R	Not stated	17/9; 2 unknown
Hsieh 2011	54 (8) years	54 (8) years	17 (7) months	28 (20) months	2 F, 8 M	1 F, 5 M	6 L, 6 R	4 L, 2 R	Not stated	15/3
Hsieh 2014	53 (10) years	54 (10) years	22 (14) months	28 (19) months	10 F, 22 M	4 F, 12 M	19 L, 13 R	7 L, 9 R	Mean 34 points FMA upper extremity	27/21
Hwang 2012	50 (4) years	51 (3) years	7 (6) months	5 (6) months	4 F, 5 M	2 F, 4 M	Not stated		Mean 43 (16) SIS activities	Not stated
Kahn 2006	56 (12) years	56 (12) years	76 (46) months	103 (48) months	6 F, 4 M	2 F, 7 M	5 L, 5 R	6 L, 3 R	Not stated	Not stated
Klamroth-Marganska 2014	55 (13) years	58 (14) years	52 (44) months	40 (45) months	17 F, 21 M	10 F, 25 M	Not stated		Mean SIS total score 63 (11)	Not stated
Kutner 2010	62 (13) years	51 (11) years	270 (111) days	184 (127) days	5 F, 5 M	2 F, 5 M	Not stated	Not stated	SIS ADL mean 59 and 68 for EXP and CTL groups, respectively	12/5
Lee 2016	50 (11) years	52 (9) years	41 (23) days	42 (20) days	7 F, 15 M	8 F, 14 M	11 L, 11 R	9 L, 13 R	Koerean Barthel Index mean 44 and 45 for EXP and CTL groups, respectively	25/19
Liao 2011	55 (11) years	54 (8) years	23 (13) months	22 (17) months	4 F, 6 M	3 F, 7 M	4 L, 6 R	3 L, 7 R	Mean 116 points FIM self-care	Not stated
Lo 2010	66 (11) years	64 (11) years	4 (4) months	5 (4) months	2 F, 47 M	3 F, 75 M	Not stated	Not stated	Mean 49 points score on SIS	108/19
Lum 2002	63 (4) years*	66 (2) years*	30 (6) months*	29 (6) months*	1 F, 12 M	6 F, 8 M	4 L, 9 R	4 L, 10 R	Mean 87 of 100 Barthel Index points	Not stated

Table 1. Participant characteristics in studies *(Continued)*

Lum 2006#	67 years	60 years	11 weeks	11 weeks	8 F, 16 M	2 F, 4 M	11 L, 13 R	2 L, 4 R	Not stated	Not stated
Masiero 2007	63 (13) years	67 (12) years	Not stated	Not stated	7 F, 10 M	7 F, 11 M	4 L, 11 R	5 L, 10 R	Not stated	Not stated
Masiero 2011	72 (7) years	76 (5) years	10 (5) days	13 (5) days	2 F, 9 M	3 F, 7 M	9 L, 2 R	8 L, 2 R	Mean total FIM 30 points	18/3
Mayr 2008	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	4 L	4 L	Not stated	6/2
McCabe 2015	21-49 years: n = 2; 50-81 years: n = 10	21-49 years: n = 5; 50-81 years: n = 18	1-3 years: n = 9; ≥ 4 years: n = 3	1-3 years: n = 18; ≥ 4 years: n = 5	2 F, 10 M	10 F, 13 M	Not stated	Not stated	23 (6) FMA upper extremity points	Not stated
Orihuela-Espina 2016	55 (26) years	56 (14) years	Not stated exactly, more than 1 week and less than 4 months post stroke		4 F, 5 M	2 F, 6 M	3 L, 5 R	3 L, 6 R	5 (3) FMA upper extremity points, Hand section	17/0
Rabadi 2008	80 (6) years	69 (11) years	10 (4) days	14 (13) days	5 F, 5 M	6 F, 14 M	Not stated	Not stated	Mean FIM score 39 (11)	3/0
Sale 2014	68 (14) years	68 (14) years	Not stated	Not stated	11 F, 15 M	11 F, 16 M	16 L, 10 R	13 L, 14 R	Mean CMSA 3 (1)	53/0
NCT03020576	55 (14) years	58 (18) years	Not stated exactly, more than 3 months post stroke		7 F, 7 M	3 F, 11 M	Not stated	Not stated	not stated	not stated
Susanto 2015	51 (9) years	55 (11) years	16 (6) months	16 (5) months	2 F, 7 M	3 F, 7 M	6 L, 3 R	6 L, 4 R	Mean FMA 33 (9)	8/11
Takahashi 2016	65 (11) years	65 (12) years	48 (7) days	47 (8) days	9 F, 21 M	8 F, 18 M	not stated	not stated	Mean FMA 30 points	Not stated
Taveggia 2016	73 (10) years	68 (13) years	between 0.5 and 12 months post stroke		18 F, 9 M	13 F, 14 M	not stated	not stated	Mean FIM 93 points	Not stated
Timmermans 2014	62 (7) years	57 (6) years	3 (3) years	4 (3) years	3 F, 8 M	3 F, 8 M	7 L, 4 R	8 L, 3 R	Mean FMA 52 points	Not stated
Tomic 2017	57 (7) years	58 (5) years	35 (10) days	37 (8) days	1 F, 12 M	4 F, 9 M	5 L, 8 R	6 L, 7 R	Mean FMA 27 points Mean NIHSS 6 points	23/3

Table 1. Participant characteristics in studies *(Continued)*

Vanoglio 2017	73 (14) years	72 (11) years	18 (8) days	15 (7) days	8 F, 7 M	8 F, 7 M	10 L, 5 R	11 L, 4 R	Mean FIM 48 points	19/11
Villafane 2017	67 (11) years	70 (12) years	between 0.5 and 12 months post onset		5 F, 11 M	6 F, 11 M	9 L, 7 R	8 L, 8 R	Mean BI 36 points Mean NIHSS 8 points	24/8
Volpe 2000	62 (2) years*	67 (2) years*	23 (1) days*	26 (1) days*	14 F, 16 M	12 F, 14 M	17 L, 13 R	14 L, 12 R	Not stated	49/7
Volpe 2008	62 (3) years*	60 (3) years*	35 (7) months*	40 (11) months*	3 F, 8 M	3 F, 7 M	5 L, 6 R	5 L, 5 R	Mean 17 points NIHSS	20/1
Wolf 2015	59 (14) years	55 (12) years	116 (53) days	127 (46) days	25 F, 26 M	17 F, 31 M	31 L, 20 R	25 L, 23 R	Mean FMA 33 (12) points	Not stated
Wu 2012	56 (11) years	51 (6) years	18 (11) months	18 (10) months	6 F, 22 M	4 F, 22 M	16 L, 12 R	10 L, 4 R	Mean FMA 44 (10) points	Not stated
Yoo 2013	51 (11) years	50 (9) years	46 (42) months	42 (33) months	4 F, 7 M	5 F, 6 M	6 L, 5 R	4 L, 7 R	Mean Barthel Index 76 (5)	15/7

*SE instead of SD
#EXP: all robot groups
ADL: activities of daily living
BI: Barthel Index
CMSA: Chedoke-McMaster Stroke Assessment
CON: control group
EXP: experimental group
F: female
FIM: Functional Independence Measure
FMA: Fugl-Meyer AssessmentL: left
L: left side
M: male
NIHSS: National Institutes of Health Stroke ScaleR
R: right side
SD: standard deviation
SE: standard error
SIS: Stroke Impact Scale

Table 2. Details of study interventions

Study ID	Duration of study	Frequency and intensity of treatment	Follow-up	Device used
Abdullah 2011	8 to 11 weeks	3 times a week (groups received the same time and frequency)	-	Adapted 5 DOF industrial robot
Amirabdollahian 2007	3 weeks	5 times a week (groups received the same time and frequency)	-	GENTLE/s
Ang 2014	6 weeks	3 times a week for 90 minutes (groups received the same time and frequency)	6 weeks and 18 weeks	Haptic Knob and Haptic Knob with Brain-Computer Interface
Brokaw 2014	3 months	12 hours within a month (groups received the same time and frequency)	-	ARMin III, HandSOME
Burgar 2011	3 weeks	1 experimental group and the control group had 15 x 1-hour therapy sessions over a 3-week period (1 robot group received 30 1-hour therapy sessions over a 3-week period)	6 months	MIME
Bustamante 2016	6 to 8 weeks	24 two-hour therapy sessions (over a period of 6 to 8 weeks)	-	Robot Gym including the TheraDrive
Conroy 2011	6 weeks	3 sessions per week for 1 hour (groups received the same time and frequency)	3 months	InMotion 2.0 Shoulder/Arm Robot
Daly 2005	12 weeks	5 hours a day, 5 days a week (groups received the same time and frequency)	3 months	InMotion
Fazekas 2007	5 weeks	Control group received 30-minute sessions on 20 consecutive workdays (Bobath, Kabat) Experimental group received same therapy as the control group, but also additional 30 minutes of robot therapy	-	REHAROB
Grigoras 2016	2 weeks	30 minutes, 5-6 times a week (groups did not received the exact same time and frequency)	-	hybrid FES-exoskeleton system
Hesse 2005	6 weeks	30 minutes, 5 times a week (groups received the same time and frequency)	3 months	Bi-Manu-Track
Hesse 2014	4 weeks	30 minutes, 5 times a week (groups received the same time and frequency)	3 months	Bi-Manu-Track, Reha-Digit, Reha-Slide, Reha-Slide Duo
Hollenstein 2011	2 weeks	5 times a week for 30 minutes (groups received the same time and frequency)	-	Armeo
Housman 2009	8 to 9 weeks	3 times a week for 1 hour (groups received the same time and frequency)	6 months	T-WREX

Table 2. Details of study interventions *(Continued)*

Hsieh 2011	4 weeks	Higher-intensity robotic training group: 20 sessions for 90 to 105 minutes, 5 days per week Lower-intensity robotic training group: same amount, but had only half of the repetitions by the device as in first group Conventional treatment group: same amount as in the other groups (groups received the same time and frequency)	-	Bi-Manu-Track
Hsieh 2014	4 weeks	Participants in each group received 20 training sessions of 90 to 105 minutes/day, 5 days/week for 4 weeks. In addition to the intervention provided in the clinics, all participants were encouraged to use their affected upper limb during activities in their daily life situations (e.g. at home) RAT + CT group (received 2 weeks robot-assisted arm therapy (Bi-Manu-Track 40 to 55 minutes plus 15 to 20 minutes conventional therapy without robot), afterwards 2 weeks constraint-induced therapy 90 to 105 minutes therapy a day and 6 hours constraint daily) RAT group (received robot-assisted arm therapy (Bi-Manu-Track) as above) CT group (received a therapist-mediated intervention using conventional occupational therapy techniques, including neurodevelopmental techniques, functional task practice, fine-motor training, arm exercises or gross-motor training, and muscle strengthening)	-	Bi-Manu-Track
Hwang 2012	4 weeks	4 weeks (20 sessions) of active robot-assisted intervention versus 2 weeks (10 sessions) of early passive therapy followed by 2 weeks (10 sessions) of active robot-assisted intervention (groups received the same time and frequency)	4 weeks	Amadeo
Kahn 2006	8 weeks	24 sessions for 45 minutes (groups received the same time and frequency)	-	ARM Guide
Klamroth-Marganska 2014	8 weeks	Robotic training or conventional therapy 3 times a week for at least 45 minutes (groups received the same time and frequency)	26 weeks	ARMin
Kutner 2010	3 weeks	1) 60 hours of repetitive-task training over the course of 3 weeks 2) 30 hours of repetitive-task training plus 30 hours of robotic-assisted training with the Hand Mentor device over the course of 3 weeks (groups received the same time and frequency)	2 months	Hand Mentor
Lee 2016	2 weeks	1) 20 sessions of 30 minutes of stretching and strengthening exercises were induced by the occupational therapists, and passive and/or active assistive ROM exercises were implemented based	-	Neuro-X system

Table 2. Details of study interventions *(Continued)*

		on the patient's motor power and ability over the course of 2 weeks 2) 20 sessions of 30 minutes of robotic-assisted training with the Neuro-X system device over the course of 2 weeks (groups received the same time and frequency)		
Liao 2011	4 weeks	5 days a week for 90 to 105 minutes per session (groups received the same time and frequency)	-	Bi-Manu-Track
Lo 2010	12 weeks	Group A: a maximum of 36 sessions over a period of 12 weeks Group B: same time and frequency Group C: usual care at different time and frequency	3, 6, 9 months	MIT-Manus
Lum 2002	8 weeks	Control group received 55 minutes of physiotherapy for the arm and 5 minutes of robot training at each of the 24 sessions Experimental group received robot therapy for the same time and frequency	8 months	MIME
Lum 2006	4 weeks	All groups received 15 1-hour treatment sessions (all groups had same time and frequency)	6 months	MIME
Masiero 2007	5 weeks	Experimental group received additional robotic training twice a day, 5 days a week Control group received similar exposure to the robot but with the unimpaired arm (both groups had same time and frequency)	3 and 8 months	NeReBot
Masiero 2011	5 weeks	Experimental group received robotic training twice a day for 20 minutes, and 40 minutes conventional training, 5 days a week Control group received conventional functional rehabilitation for 80 minutes a day (groups received the same time and frequency)	3 months	NeReBot
Mayr 2008	6 weeks	5 times per week (both groups received the same time and frequency)	-	ARMOR
McCabe 2015	5 weeks	5 hours per day for 12 weeks (all groups received the same time and frequency)	-	InMotion2 Shoulder/Elbow Robot
Orihuela-Espina 2016	8-10 weeks	Both groups received therapy 5 times per week until they completed 40 sessions	-	Amadeo, Tyromotion
Rabadi 2008	Not stated	Standard occupational and physical therapy for 3 hours per day + 12 additional sessions of 40 minutes of either occupational therapy, arm ergometry, or robotic-assisted training for 5 days per week	-	MIT-Manus
Sale 2014	6 weeks	30 sessions of robot-assisted therapy (5 days a week for 6 weeks) versus 30 sessions (5 days a week for 6 weeks) of conventional rehabilitative treatment	-	MIT-Manus/InMotion2

Table 2. Details of study interventions *(Continued)*

		Experimental and control therapies were applied in addition to usual rehabilitation (groups received the same time and frequency)		
NCT03020576	8 weeks	5 times per week for 8 weeks in both groups (groups received the same time and frequency) Conventional therapy involved treatment and methods designed to promote range of motion, strength, coordination and function at the level of the shoulder, elbow, wrist and hand Robotic therapy was done to improve range of motion, strength, and coordination to the wrist and hand		Amadeo Hand, Tyromotion
Susanto 2015	5 weeks	Hand exoskeleton robot-assisted training for 20 1-hour sessions versus control group (non-assisted group) for 20 1-hour sessions (groups received the same time and frequency)	6 months	Self designed hand exoskeleton robot
Takahashi 2016	6 weeks	7 times per week in 40 minutes sessions for 6 weeks in both groups (groups received the same time and frequency) (standard therapy plus 40 minutes of either robotic therapy with the ReoGo or self-guided therapy)	-	ReoGo, Motorika Medical, Caesaria, Israel
Taveggia 2016	6 weeks	5 times per week in 30 minutes for 6 weeks in both groups (groups received the same time and frequency) Conventional therapy involved upper limb traditional treatment based on the Bobath concept Robotic therapy was done to improve range of motion, strength, and coordination to the wrist and hand	6 weeks	Armeo Spring
Timmermans 2014	8 weeks	Robotic-assisted training with the end-effector robot HapticMaster versus arm-hand training programme during 8 weeks, 4 times/week, twice a day for 30 minutes (groups received the same time and frequency)	6 month	HapticMaster
Tomic 2017	3 weeks	Robot therapy with the ArmAssist for 30 minutes was administered over 15 sessions each lasting 30 minutes, scheduled 5 days per week (Monday–Friday) for 3 weeks, and the control group received occupational therapy for 30 minutes that was matched in its structure and amount to the ArmAssist training as closely as possible (groups received the same time and frequency of therapy)	-	ArmAssist
Vanoglio 2017	30 days	The specific hand intervention consisted of a total of 30 sessions, lasting 40 minutes/day, for 5 days/week in both groups In the control group, the affected hand was passively moved by the physiotherapist: 1) flexion-ex-	-	Gloreha

Table 2. Details of study interventions *(Continued)*

		tension of the fingers (10 minutes), 2) thumb opposition with the other fingers keeping the forearm in supine position (10 minutes), 3) adduction and abduction of the fingers (10 minutes), 4) global movement of the hand consisting in reaching for a 0.5 L empty bottle of water, taking hold of it, simulating the pouring of water into a glass, and then putting the bottle down and letting go of it (10 minutes) In the treatment group, the affected hand was passively moved by the glove Gloreha Professional and each training session consisted of 6 parts: 1) a sequence of 17 cycles of movements including digital joint flexion/extension exercises, from the thumb to the fifth finger (7 minutes), 2) a sequence of 23 cycles of movements for 7 minutes (counting from 1 to 5), 3) a sequence of 70 cycles of movements including thumb-finger opposition movements from the 2nd to the 5th finger (7 minutes), 4) a sequence of 28 cycles of movements including wave-like finger movements (7 minutes), 5) a sequence of 42 cycles of movements including fist opening/closing (7 minutes), 6) a sequence of 20 cycles of movements including flexion-extension of the fingers alternated with flexion-extension of the thumb (5 minutes)		
Villafane 2017	3 weeks	30 minutes a day, for 15 days over 3 weeks in both groups The treatment group used the Gloreha to mobilise each finger individually (passive movement of flexion-extension) and simultaneously, but the thumb individually with providing visual feedback Participants in the control group received the same number of treatment sessions of a similar duration as those in the experimental group, and received assisted stretching, shoulder and arm exercises, and functional reaching tasks	-	Gloreha
Volpe 2000	5 weeks	1 hour per day, 5 days a week (for at least 25 sessions) (both groups received the same time and frequency)	-	MIT-Manus
Volpe 2008	6 weeks	1 hour per session, 3 times a week (both groups received the same time and frequency)	3 months	InMotion2
Wolf 2015	8 weeks	3 hours per session, 5 days a week for 8 weeks Home exercises and therapy with the Hand Mentor Pro and control group received home exercises only, but both groups had an identical dosage of therapy.		Hand Mentor Pro
Wu 2012	4 weeks	Therapist-mediated bilateral arm training (CT group) versus robot-assisted (Bi-Manu-Track) arm trainer (RAT group) versus conventional therapy (involved weight bearing, stretching, strengthening of the paretic arms, coordination, unilateral and bilateral fine-motor tasks, balance, and compensatory practice on functional tasks; CT group). Each	-	Bi-Manu-Track

Table 2. Details of study interventions *(Continued)*

		group received treatment for 90 to 105 minutes per session, 5 sessions on weekdays, for 4 weeks (groups received the same time and frequency)		
Yoo 2013	6 weeks	3-dimensional robot-assisted therapy (RAT) and conventional rehabilitation therapy (CT) for a total of 90 minutes (RAT: 30 minutes, CT: 60 minutes) a day with 10 minutes rest halfway through the session, received training 3 days a week for 6 weeks. The control group received therapy only 60 minutes a day on the same days as the first group	-	ReoGo

CT: control therapy
DOF: degrees of freedom
L: left side
MIME: mirror image motion enabler
RAT: robot-assisted therapy
ROM: range of motion

APPENDICES

Appendix 1. CENTRAL search strategy

Cochrane Central Register of Controlled Trials (CENTRAL) The Cochrane Library

#1 [mh ^"cerebrovascular disorders"] or [mh "basal ganglia cerebrovascular disease"] or [mh "brain ischemia"] or [mh "carotid artery diseases"] or [mh "cerebral small vessel diseases"] or [mh "intracranial arterial diseases"] or [mh "intracranial embolism and thrombosis"] or [mh "intracranial hemorrhages"] or [mh ^stroke] or [mh "brain infarction"] or [mh ^"stroke, lacunar"] or [mh ^"vasospasm, intracranial"] or [mh ^"vertebral artery dissection"] or [mh ^"brain injuries"] or [mh ^"brain injury, chronic"]

#2 (stroke* or poststroke or apoplex* or cerebral next vasc* or brain next vasc* or cerebrovasc* or cva* or SAH):ti,ab

#3 ((brain or cerebr* or cerebell* or vertebrobasil* or hemispher* or intracran* or intracerebral or infratentorial or supratentorial or "middle cerebral artery" or MCA* or "anterior circulation" or "posterior circulation" or "basilar artery" or "vertebral artery" or "space-occupying") near/5 (isch*emi* or infarct* or thrombo* or emboli* or occlus* or hypoxi*)):ti,ab

#4 ((brain* or cerebr* or cerebell* or intracerebral or intracran* or parenchymal or intraparenchymal or intraventricular or infratentorial or supratentorial or basal next gangli* or putaminal or putamen or "posterior fossa" or hemispher* or subarachnoid) near/5 (hemorrhag* or haemorrhage* or hematoma* or haematoma* or bleed*)):ti,ab

#5 [mh ^hemiplegia] or [mh paresis]

#6 (hemipleg* or hemipar* or paresis or paretic or brain next injur*):ti,ab

#7 #1 or #2 or #3 or #4 or #5 or #6

#8 [mh "upper extremity"]

#9 (upper next limb* or upper next extremit* or arm or arms or shoulder or shoulders or hand or hands or axilla* or elbow* or forearm* or finger* or wrist*):ti,ab

#10 #8 or #9

#11 [mh robotics] or [mh automation] or [mh "orthotic devices"]

#12 [mh "equipment and supplies"] or [mh "self-help devices"]

#13 [mh "physical therapy modalities"] or [mh "occupational therapy"]

#14 [mh "therapy, computer-assisted"] or [mh "man-machine systems"]

#15 [mh "exercise movement techniques"] or [mh exercise] or [mh "exercise therapy"] or [mh "muscle stretching techniques"] or [mh "motion therapy, continuous passive"]

#16 (robot* or orthos* or orthotic or automat* or computer next aided or computer next assisted or device*):ti,ab

#17 (electromechanical or "electro-mechanical" or mechanical or mechanised or mechanized or driven):ti,ab

#18 ((continuous passive or cpm) near/3 therap*):ti,ab

#19 (MIT-Manus or ARM guide or Bi-Manu-Track or ARMtrainer or MIME or Mirror-Image Motion Enabler or InMOTION or REHAROB or NeReBot or "GENTLE/S" or ARMin):ti,ab

#20 (assist* near/5 (train* or aid* or rehabilitat* or re-educat*)):ti,ab

#21 #11 or #12 or #13 or #14 or #15 or #16 or #17 or #18 or #19 or #20

#22 #7 and #10 and #21

Number of hits: n=1611

Appendix 2. MEDLINE (Ovid) search strategy

MEDLINE (Ovid) Revised March 2015

1. cerebrovascular disorders/ or exp basal ganglia cerebrovascular disease/ or exp brain ischemia/ or exp carotid artery diseases/ or exp cerebral small vessel diseases/ or exp intracranial arterial diseases/ or exp "intracranial embolism and thrombosis"/ or exp intracranial hemorrhages/ or stroke/ or exp brain infarction/ or stroke, lacunar/ or vasospasm, intracranial/ or vertebral artery dissection/ or brain injuries/ or brain injury, chronic/

2. (stroke$ or poststroke or apoplex$ or cerebral vasc$ or brain vasc$ or cerebrovasc$ or cva$ or SAH).tw.

3. ((brain or cerebr$ or cerebell$ or vertebrobasil$ or hemispher$ or intracran$ or intracerebral or infratentorial or supratentorial or middle cerebral artery or MCA$ or anterior circulation or posterior circulation or basilar artery or vertebral artery or space-occupying) adj5 (isch? emi$ or infarct$ or thrombo$ or emboli$ or occlus$ or hypoxi$)).tw.

4. ((brain$ or cerebr$ or cerebell$ or intracerebral or intracran$ or parenchymal or intraparenchymal or intraventricular or infratentorial or supratentorial or basal gangli$ or putaminal or putamen or posterior fossa or hemispher$ or subarachnoid) adj5 (h?emorrhag$ or h? ematoma$ 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. exp upper extremity/

9. (upper limb$ or upper extremit$ or arm or arms or shoulder or shoulders or hand or hands or axilla$ or elbow$ or forearm$ or finger $ or wrist$).tw.

10. 8 or 9

11. robotics/ or automation/ or orthotic devices/

12. "equipment and supplies"/ or self-help devices/

13. physical therapy modalities/ or occupational therapy/

14. therapy, computer-assisted/ or man-machine systems/

15. exercise movement techniques/ or exercise/ or exercise therapy/ or muscle stretching techniques/ or motion therapy, continuous passive/

16. (robot$ or orthos$ or orthotic or automat$ or computer aided or computer assisted or device$).tw.

17. (electromechanical or electro-mechanical or mechanical or mechanised or mechanized or driven).tw.

18. ((continuous passive or cpm) adj3 therap$).tw.

19. (MIT-Manus or ARM guide or Bi-Manu-Track or ARMtrainer or MIME or Mirror-Image Motion Enabler or InMOTION or REHAROB or NeReBot or "GENTLE/S" or ARMin).tw.

20. (assist$ adj5 (train$ or aid$ or rehabilitat$ or re-educat$)).tw.

21. or/11-20

22. Randomized Controlled Trials as Topic/

23. random allocation/

24. Controlled Clinical Trials as Topic/

25. control groups/

26. clinical trials as topic/ or clinical trials, phase i as topic/ or clinical trials, phase ii as topic/ or clinical trials, phase iii as topic/ or clinical trials, phase iv as topic/

27. double-blind method/

28. single-blind method/

29. Placebos/

30. placebo effect/

31. cross-over studies/

32. randomized controlled trial.pt.

33. controlled clinical trial.pt.

34. (clinical trial or clinical trial phase i or clinical trial phase ii or clinical trial phase iii or clinical trial phase iv).pt.

35. (random$ or RCT or RCTs).tw.

36. (controlled adj5 (trial$ or stud$)).tw.

37. (clinical$ adj5 trial$).tw.

38. ((control or treatment or experiment$ or intervention) adj5 (group$ or subject$ or patient$)).tw.

39. (quasi-random$ or quasi random$ or pseudo-random$ or pseudo random$).tw.

40. ((control or experiment$ or conservative) adj5 (treatment or therapy or procedure or manage$)).tw.

41. ((singl$ or doubl$ or tripl$ or trebl$) adj5 (blind$ or mask$)).tw.

42. (cross-over or cross over or crossover).tw.

43. (placebo$ or sham).tw.

44. trial.ti.

45. (assign$ or allocat$).tw.

46. controls.tw.

47. or/22-46

48. 7 and 10 and 21 and 47

49. exp animals/ not humans.sh.

50. 48 not 49

Number of hits: n=1949

Appendix 3. Embase (Ovid) search strategy

Embase (Ovid) Revised March 2015

1. cerebrovascular disease/ or exp basal ganglion hemorrhage/ or exp brain hematoma/ or exp brain hemorrhage/ or exp brain infarction/ or exp brain ischemia/ or exp carotid artery disease/ or cerebral artery disease/ or exp cerebrovascular accident/ or exp intracranial aneurysm/ or exp occlusive cerebrovascular disease/ or stroke unit/ or stroke patient/ or brain injury/ or acquired brain injury/

2. (stroke$ or poststroke or apoplex$ or cerebral vasc$ or brain vasc$ or cerebrovasc$ or cva$ or SAH).tw.

3. ((brain or cerebr$ or cerebell$ or vertebrobasil$ or hemispher$ or intracran$ or intracerebral or infratentorial or supratentorial or middle cerebral artery or MCA$ or anterior circulation or posterior circulation or basilar artery or vertebral artery or space-occupying) adj5 (isch? emi$ or infarct$ or thrombo$ or emboli$ or occlus$ or hypoxi$)).tw.

4. ((brain$ or cerebr$ or cerebell$ or intracerebral or intracran$ or parenchymal or intraparenchymal or intraventricular or infratentorial or supratentorial or basal ganglia$ or putaminal or putamen or posterior fossa or hemispher$ or subarachnoid) adj5 (h?emorrhag$ or h? ematoma$ or bleed$)).tw.

5. hemiparesis/ or hemiplegia/ or paresis/

6. (hemipleg$ or hemipar$ or paresis or paretic or brain injur$).tw.

7. 1 or 2 or 3 or 4 or 5 or 6

8. exp arm/ or arm weakness/ or arm exercise/ or arm movement/

9. (upper limb$ or upper extremit$ or arm or arms or shoulder or shoulders or hand or hands or axilla$ or elbow$ or forearm$ or finger $ or wrist$).tw.

10. 8 or 9

11. robotics/ or automation/ or orthotics/

12. man machine interaction/ or biomedical engineering/ or device/ or machine/ or assistive technology/ or assistive technology device/ or computer assisted therapy/

13. passive movement/ or movement therapy/ or kinesiotherapy/ or exp exercise/ or muscle stretching/ or muscle training/

14. (robot$ or orthos$ or orthotic or automat$ or computer aided or computer assisted or computeri?ed or device$).tw.

15. (electromechanical or electro-mechanical or mechanical or mechanised or mechanized or driven).tw.

16. ((continuous passive or cpm) adj3 therap$).tw.

17. (MIT-Manus or ARM guide or Bi-Manu-Track or ARMtrainer or MIME or Mirror-Image Motion Enabler or InMOTION or REHAROB or NeReBot or "GENTLE/S" or ARMin).tw.

18. (assist$ adj5 (train$ or aid$ or rehabilitat$ or re-educat$)).tw.

19. or/11-18

20. Randomized Controlled Trial/ or "randomized controlled trial (topic)"/

21. Randomization/

22. Controlled clinical trial/ or "controlled clinical trial (topic)"/

23. control group/ or controlled study/

24. clinical trial/ or "clinical trial (topic)"/ or phase 1 clinical trial/ or phase 2 clinical trial/ or phase 3 clinical trial/ or phase 4 clinical trial/

25. Crossover Procedure/

26. Double Blind Procedure/

27. Single Blind Procedure/ or triple blind procedure/

28. placebo/ or placebo effect/

29. (random$ or RCT or RCTs).tw.

30. (controlled adj5 (trial$ or stud$)).tw.

31. (clinical$ adj5 trial$).tw.

32. ((control or treatment or experiment$ or intervention) adj5 (group$ or subject$ or patient$)).tw.

33. (quasi-random$ or quasi random$ or pseudo-random$ or pseudo random$).tw.

34. ((control or experiment$ or conservative) adj5 (treatment or therapy or procedure or manage$)).tw.

35. ((singl$ or doubl$ or tripl$ or trebl$) adj5 (blind$ or mask$)).tw.

36. (cross-over or cross over or crossover).tw.

37. (placebo$ or sham).tw.

38. trial.ti.

39. (assign$ or allocat$).tw.

40. controls.tw.

41. or/20-40

42. 7 and 10 and 19 and 41

43. (exp animals/ or exp invertebrate/ or animal experiment/ or animal model/ or animal tissue/ or animal cell/ or nonhuman/) not (human/ or normal human/ or human cell/)

44. 42 not 43

Number of hits: n=4195

Appendix 4. CINAHL (Ebsco) search strategy

CINAHL (Ebsco) Revised March 2015

S1 .(MH "Cerebrovascular Disorders") OR (MH "Basal Ganglia Cerebrovascular Disease+") OR (MH "Carotid Artery Diseases+") OR (MH "Cerebral Ischemia+") OR (MH "Cerebral Vasospasm") OR (MH "Intracranial Arterial Diseases+") OR (MH "Intracranial Embolism and Thrombosis") OR (MH "Intracranial Hemorrhage+") OR (MH "Stroke") OR (MH "Vertebral Artery Dissections") OR .(MH "Brain Injuries")

S2 .(MH "Stroke Patients") OR (MH "Stroke Units")

S3 .TI (stroke* or poststroke or apoplex* or cerebral vasc* or brain vasc* or cerebrovasc* or cva* or SAH) or AB (stroke* or poststroke or apoplex* or cerebral vasc* or brain vasc* or cerebrovasc* or cva* or SAH)

S4 .TI (brain or cerebr* or cerebell* or vertebrobasil* or hemispher* or intracran* or intracerebral or infratentorial or supratentorial or middle cerebral artery or MCA* or anterior circulation or posterior circulation or basilar artery or vertebral artery or space-occupying) or AB (brain or cerebr* or cerebell* or vertebrobasil* or hemispher* or intracran* or intracerebral or infratentorial or supratentorial or middle cerebral artery or MCA* or anterior circulation or posterior circulation or basilar artery or vertebral artery or space-occupying)

S5 .TI (ischemi* or ischaemi* or infarct* or thrombo* or emboli* or occlus* or hypoxi*) or AB (ischemi* or ischaemi* or infarct* or thrombo* or emboli* or occlus* or hypox*)

S6 .S4 and S5

S7 .TI (brain* or cerebr* or cerebell* or intracerebral or intracran* or parenchymal or intraparenchymal or intraventricular or infratentorial or supratentorial or basal gangli* or putaminal or putamen or posterior fossa or hemispher* or subarachnoid) or AB (brain* or cerebr* or cerebell* or intracerebral or intracran* or parenchymal or intraparenchymal or intraventricular or infratentorial or supratentorial or basal gangli* or putaminal or putamen or posterior fossa or hemispher* or subarachnoid)

S8 .TI (haemorrhage* or hemorrhage* or haematoma* or hematoma* or bleed*) or AB (haemorrhage* or hemorrhage* or haematoma* or hematoma* or bleed*)

S9 .S7 and S8

S10 ..(MH "Hemiplegia")

S11 .TI (hemipleg* or hemipar* or paresis or paretic or brain injur*) or AB (hemipleg* or hemipar* or paresis or paretic or brain injur*)

S12 .S1 OR S2 OR S3 OR S6 OR S9 OR S10 OR S11

S13 .(MH "Upper Extremity+")

S14 .TI (upper limb* or upper extremit* or arm or arms or shoulder or shoulders or hand or hands or axilla* or elbow* or forearm* or finger* or wrist*) or AB (upper limb* or upper extremit* or arm or arms or shoulder or shoulders or hand or hands or axilla* or elbow* or forearm* or finger* or wrist*)

S15 .S13 or S14

S16 ..(MH "Therapeutic Exercise") OR (MH "Motion Therapy, Continuous Passive") OR (MH "Muscle Strengthening+") OR (MH "Neuromuscular Facilitation") OR (MH "Upper Extremity Exercises+")

S17 .(MH "Exercise+")

S18 .(MH "Movement+")

S19 .(MH "Assistive Technology") OR (MH "Automation") OR (MH "Robotics")

S20 .(MH "Orthoses") OR (MH "Orthoses Design")

S21 .(MH "Biomedical Engineering") OR (MH "Assistive Technology Services")

S22 .(MH "Assistive Technology Devices") OR (MH "Equipment and Supplies")

S23 .(MH "Therapy, Computer Assisted

S24 .(MH "Biomechanics")

S25 .TI (robot* or orthos* or orthotic or automat* or computer aided or computer assisted or device*) OR AB (robot* or orthos* or orthotic or automat* or computer aided or computer assisted or device*)

S26 .TI (electromechanical or electro-mechanical or mechanical or mechanised or mechanized or driven) OR AB (electromechanical or electro-mechanical or mechanical or mechanised or mechanized or driven)

S27 .TI (continuous passive or cpm) OR AB (continuous passive or cpm)

S28 .TI therap* OR AB therap*

S29 .S27 and S28

S30 .TI (MIT-Manus or ARM guide or Bi-Manu-Track or ARMtrainer or MIME or Mirror-Image Motion Enabler or InMOTION or REHAROB or NeReBot or "GENTLE/S" or ARMin) OR AB (MIT-Manus or ARM guide or Bi-Manu-Track or ARMtrainer or MIME or Mirror-Image Motion Enabler or InMOTION or REHAROB or NeReBot or "GENTLE/S" or ARMin)

S31 .TI assist* OR AB assist*

S32 .TI (train* or aid* or rehabilitat* or re-educat*) OR AB (train* or aid* or rehabilitat* or re-educat*)

S33 .S31 AND S32

S34 .S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S29 OR S30 OR S33

S35 .(MH "Randomized Controlled Trials") or (MH "Random Assignment") or (MH "Random Sample+")

S36 .(MH "Clinical Trials") or (MH "Intervention Trials") or (MH "Therapeutic Trials")

S37 .(MH "Double-Blind Studies") or (MH "Single-Blind Studies") or (MH "Triple-Blind Studies")

S38 .(MH "Control (Research)") or (MH "Control Group") or (MH "Placebos") or (MH "Placebo Effect")

S39 .(MH "Crossover Design") OR (MH "Quasi-Experimental Studies")

S40 .PT (clinical trial or randomized controlled trial)

S41 .TI (random* or RCT or RCTs) or AB (random* or RCT or RCTs)

S42 .TI (controlled N5 (trial* or stud*)) or AB (controlled N5 (trial* or stud*))

S43 .TI (clinical* N5 trial*) or AB (clinical* N5 trial*)

S44 .TI ((control or treatment or experiment* or intervention) N5 (group* or subject* or patient*)) or AB ((control or treatment or experiment* or intervention) N5 (group* or subject* or patient*))

S45 .TI ((control or experiment* or conservative) N5 (treatment or therapy or procedure or manage*)) or AB ((control or experiment* or conservative) N5 (treatment or therapy or procedure or manage*))

S46 .TI ((singl* or doubl* or tripl* or trebl*) N5 (blind* or mask*)) or AB ((singl* or doubl* or tripl* or trebl*) N5 (blind* or mask*))

S47 .TI (cross-over or cross over or crossover) or AB (cross-over or cross over or crossover)

S48 .TI (placebo* or sham) or AB (placebo* or sham)

S49 .TI trial

S50 .TI (assign* or allocat*) or AB (assign* or allocat*)

S51 .TI controls or AB controls

S52 .TI (quasi-random* or quasi random* or pseudo-random* or pseudo random*) or AB (quasi-random* or quasi random* or pseudo-random* or pseudo random*)

S53 .S35 OR S36 OR S37 OR S38 OR S39 OR S40 OR S41 OR S42 OR S43 OR S44 OR S45 OR S46 OR S47 OR S48 OR S49 OR S50 OR S51 OR S52

S54 .S12 AND S15 AND S34 AND S53

Number of hits: n=1576

Appendix 5. AMED (Ovid) search strategy

1. cerebrovascular disorders/ or cerebral hemorrhage/ or cerebral infarction/ or cerebral ischemia/ or cerebrovascular accident/ or stroke/ or brain injuries/

2. (stroke$ or poststroke or apoplex$ or cerebral vasc$ or brain vasc$ or cerebrovasc$ or cva$ or SAH).tw.

3. ((brain or cerebr$ or cerebell$ or vertebrobasil$ or hemispher$ or intracran$ or intracerebral or infratentorial or supratentorial or middle cerebral artery or MCA$ or anterior circulation or posterior circulation or basilar artery or vertebral artery or space-occupying) adj5 (isch? emi$ or infarct$ or thrombo$ or emboli$ or occlus$ or hypoxi$)).tw.

4. ((brain$ or cerebr$ or cerebell$ or intracerebral or intracran$ or parenchymal or intraparenchymal or intraventricular or infratentorial or supratentorial or basal gangli$ or putaminal or putamen or posterior fossa or hemispher$ or subarachnoid) adj5 (h?emorrhag$ or h? ematoma$ or bleed$)).tw.

5. hemiplegia/

6. (hemipleg$ or hemipar$ or paresis or paretic or brain injur$).tw.

7. or/1-6

8. exp arm/

9. (upper limb$ or upper extremit$ or arm or arms or shoulder or shoulders or hand or hands or axilla$ or elbow$ or forearm$ or finger $ or wrist$).tw.

10. 8 or 9

11. robotics/ or orthotic devices/ or biomechanics/ or equipment design/ or equipment/ or biomechanics equipment/ or therapy computer assisted/

12. exercise/ or exercise movement techniques/ or exercise therapy/ or exp movement/ or continuous passive motion/

13. engineering/ or technology/ or technology medical/

14. (robot$ or orthos$ or orthotic or automat$ or computer aided or computer assisted or device$).tw.

15. (electromechanical or electro-mechanical or mechanical or mechanised or mechanized or driven).tw.

16. ((continuous passive or cpm) adj3 therap$).tw.

17. (MIT-Manus or ARM guide or Bi-Manu-Track or ARMtrainer or MIME or Mirror-Image Motion Enabler or InMOTION or REHAROB or NeReBot or "GENTLE/S" or ARMin).tw.

18. (assist$ adj5 (train$ or aid$ or rehabilitat$ or re-educat$)).tw.

19. or/11-18

20. clinical trials/ or randomized controlled trials/ or random allocation/

21. research design/ or comparative study/

22. double blind method/ or single blind method/

23. placebos/

24. (random$ or RCT or RCTs).tw.

25. (controlled adj5 (trial$ or stud$)).tw.

26. (clinical$ adj5 trial$).tw.

27. ((control or treatment or experiment$ or intervention) adj5 (group$ or subject$ or patient$)).tw.

28. (quasi-random$ or quasi random$ or pseudo-random$ or pseudo random$).tw.

29. ((control or experiment$ or conservative) adj5 (treatment or therapy or procedure or manage$)).tw.

30. ((singl$ or doubl$ or tripl$ or trebl$) adj5 (blind$ or mask$)).tw.

31. (cross-over or cross over or crossover).tw.

32. (placebo$ or sham).tw.

33. trial.ti.

34. (assign$ or allocat$).tw.

35. controls.tw.

36. or/20-35

37. 7 and 10 and 19 and 36

Number of hits: n=465

Appendix 6. SPORTDiscus (Ebsco) search strategy

SportDISCUS (Ebsco) Revised march 2015

S1 .DE "CEREBROVASCULAR disease" OR DE "BRAIN -- Hemorrhage" OR DE "CEREBRAL embolism & thrombosis" OR DE "STROKE" OR DE "BRAIN -- Wounds & injuries" OR DE "BRAIN damage"

S2 .DE "CEREBROVASCULAR disease -- Patients"

S3 .TI (stroke* or poststroke or apoplex* or cerebral vasc* or brain vasc* or cerebrovasc* or cva* or SAH) or AB (stroke* or poststroke or apoplex* or cerebral vasc* or brain vasc* or cerebrovasc* or cva* or SAH)

S4 .TI (brain or cerebr* or cerebell* or vertebrobasil* or hemispher* or intracran* or intracerebral or infratentorial or supratentorial or middle cerebral artery or MCA* or anterior circulation or posterior circulation or basilar artery or vertebral artery or space-occupying) or AB (brain or cerebr* or cerebell* or vertebrobasil* or hemispher* or intracran* or intracerebral or infratentorial or supratentorial or middle cerebral artery or MCA* or anterior circulation or posterior circulation or basilar artery or vertebral artery or space-occupying)

S5 .TI (ischemi* or ischaemi* or infarct* or thrombo* or emboli* or occlus* or hypoxi*) or AB (ischemi* or ischaemi* or infarct* or thrombo* or emboli* or occlus* or hypox*)

S6 .S4 AND S5

S7 .TI (brain* or cerebr* or cerebell* or intracerebral or intracran* or parenchymal or intraparenchymal or intraventricular or infratentorial or supratentorial or basal gangli* or putaminal or putamen or posterior fossa or hemispher* or subarachnoid) or AB (brain* or cerebr* or cerebell* or intracerebral or intracran* or parenchymal or intraparenchymal or intraventricular or infratentorial or supratentorial or basal gangli* or putaminal or putamen or posterior fossa or hemispher* or subarachnoid)

S8 .TI (haemorrhage* or hemorrhage* or haematoma* or hematoma* or bleed*) or AB (haemorrhage* or hemorrhage* or haematoma* or hematoma* or bleed*)

S9 .S7 AND S8

S10 .DE "HEMIPLEGIA" OR DE "HEMIPLEGICS"

S11 .TI (hemipleg* or hemipar* or paresis or paretic or brain injur*) or AB (hemipleg* or hemipar* or paresis or paretic or brain injur*)

S12 .S1 OR S2 OR S3 OR S6 OR S9 OR S10 OR S11

S13 .DE "ARM" OR DE "BICEPS brachii" OR DE "ELBOW" OR DE "FOREARM" OR DE "HAND" OR DE "HUMERUS" OR DE "TRICEPS" OR DE "WRIST" OR DE "ARM exercises" OR DE "HAND exercises" OR DE "SHOULDER exercises"

S14 .TI (upper limb* or upper extremit* or arm or arms or shoulder or shoulders or hand or hands or axilla* or elbow* or forearm* or finger* or wrist*) or AB (upper limb* or upper extremit* or arm or arms or shoulder or shoulders or hand or hands or axilla* or elbow* or forearm* or finger* or wrist*)

S15 .S13 OR S14

S16 .DE "EXERCISE" OR DE "EXERCISE therapy" OR DE "STRENGTH training" OR DE "MOVEMENT therapy" OR DE "SELF-help devices for people with disabilities" OR DE "ROBOTICS in sports"

S17 .DE "ORTHOPEDIC apparatus" OR DE "EQUIPMENT & supplies" OR DE "ORTHOPEDIC braces" OR DE "ORTHOPEDIC slings"

S18 .DE "BIOMEDICAL engineering"

S19 .DE "ELECTRONIC games" OR DE "COMPUTER games" OR DE "INTERNET games" OR DE "VIDEO games"

S20 .DE "BIOMECHANICS"

S21 .TI (robot* or orthos* or orthotic or automat* or computer aided or computer assisted or device*) OR AB (robot* or orthos* or orthotic or automat* or computer aided or computer assisted or device*)

S22 .TI (electromechanical or electro-mechanical or mechanical or mechanised or mechanized or driven) OR AB (electromechanical or electro-mechanical or mechanical or mechanised or mechanized or driven)

S23 .TI (continuous passive or cpm) OR AB (continuous passive or cpm)

S24 .TI therap* OR AB therap*

S25 .S23 AND S24

S26 .TI (MIT-Manus or ARM guide or Bi-Manu-Track or ARMtrainer or MIME or Mirror-Image Motion Enabler or InMOTION or REHAROB or NeReBot or "GENTLE/S" or ARMin) OR AB (MIT-Manus or ARM guide or Bi-Manu-Track or ARMtrainer or MIME or Mirror-Image Motion Enabler or InMOTION or REHAROB or NeReBot or "GENTLE/S" or ARMin)

S27 .TI assist* OR AB assist*

S28 .TI (train* or aid* or rehabilitat* or re-educat*) OR AB (train* or aid* or rehabilitat* or re-educat*)

S29 .S27 AND S28

S30 .S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S25 OR S26 OR S29

S31 .S12 AND S15 AND S30

Number of hits: n=927

Appendix 7. PEDro search strategy

Abstract &Title: robot*

Subdiscipline: neurology

Method: clinical trial

When searching: Match all search terms (AND)

Number of hits: 168

Appendix 8. Compendex and Inspec (Institution of Engineering and Technology) search strategy

Compendex and Inspec
((((robot* or orthos* or orthotic or automat* or computer aided or computer assisted or device* or electromechanical or electro-mechanical or mechanical or mechanised or mechanized or driven or MIT-Manus or ARM guide or Bi-Manu-Track or ARMtrainer or MIME or Mirror-Image Motion Enabler or InMOTION or REHAROB or NeReBot or "GENTLE/S" or ARMin) WN KY) AND ((stroke or cerebrovascular or poststroke or post-stroke or hemipleg*) WN TI)) AND ((upper limb* or upper extremit* or arm* or shoulder* or hand* or axilla* or elbow* or forearm* or finger* or wrist*) WN KY))

Number of hits Compendex: n=3735

Number of hits Inspec: n=3240

Appendix 9. ISRCTN Registry search strategy

(arm OR upper limb) AND stroke [Condition]

Number of hits: 66

Appendix 10. US National Institutes of Health Ongoing Trials Register (ClinicalTrials.gov) search strategy

(robot OR orthotic OR computer OR automation OR electromechanical OR mechanised) AND Stroke [DISEASE]

Number of hits: 326

Appendix 11. Stroke Trials Registry search strategy

Keywords: robot

Number of hits: 201

Appendix 12. World Health Organization International Clinical Trials Registry Platform search strategy

stroke OR cerebral OR cerebrovascular or intracranial: CONDITION

AND

robot OR orthotic OR computer OR automation OR electromechanical OR mechanized OR mechanised: INTERVENTION

Number of hits: 284

WHAT'S NEW

Date	Event	Description
15 March 2018	New search has been performed	We have updated the searches to January 2018, and revised the text as appropriate. We have included 45 trials with 1619 participants in this update compared with 34 trials with 1160 participants in the 2015 version of this review.
15 March 2018	New citation required and conclusions have changed	The conclusions of the review have changed. The previous version concluded that people who receive electromechanical and

Date	Event	Description
		robot-assisted arm training after stroke are more likely to improve their activities of daily living, arm function, and arm muscle strength. This updated version concluded that people who receive electromechanical and robot-assisted arm training after stroke might improve their activities of daily living, arm function, and arm muscle strength.

HISTORY

Protocol first published: Issue 1, 2008
Review first published: Issue 4, 2008

Date	Event	Description
2 June 2015	New search has been performed	We have updated the searches to March 2015, and revised the text as appropriate. We have included 34 trials with 1160 participants in this update compared with 19 trials with 666 participants in the 2011 version of this review.
2 June 2015	New citation required and conclusions have changed	The conclusions of the review have changed. The previous version concluded that people who receive electromechanical and robot-assisted arm training after stroke were more likely to improve their activities of daily living, paretic arm function may improve, but arm strength did not improve. This updated version concluded that people who receive electromechanical and robot-assisted arm training after stroke are more likely to improve their activities of daily living, arm function, and arm muscle strength.
27 October 2011	New citation required and conclusions have changed	The conclusions of the review have changed. The previous version of this review concluded that people who receive electromechanical and robot-assisted arm training after stroke are not more likely to improve their generic activities of daily living, but arm function and muscle strength of the paretic arm may improve. This updated version of the review concluded that people who receive electromechanical and robot-assisted arm training after stroke are more likely to improve their activities of daily living, and paretic arm function may improve, but not arm strength.
9 August 2011	New search has been performed	We have updated the searches to July and August 2011, and revised the text as appropriate. We have included 19 trials with 666 participants in this update compared with 11 trials with 328 participants in the 2008 version of this review.
31 March 2008	Amended	Converted to new review format.

CONTRIBUTIONS OF AUTHORS

Jan Mehrholz contributed to the conception and design of the protocol and approved the final manuscript. He searched electronic databases and conference proceedings, screened titles and abstracts of publications identified by the search, selected and assessed trials,

extracted trial and outcome data, guided the analysis and interpretation of the data, and contributed to and approved the final manuscript of the review.

Marcus Pohl extracted trial and outcome data, contributed to the conception and design of the review, and drafted the protocol. Together with Jan Mehrholz, he contacted trialists about unpublished data and also entered the data, carried out statistical analysis, helped with the interpretation of the data, drafted the review, and approved the final manuscript of the review.

Thomas Platz contributed to the interpretation of the data and approved the final manuscript of the review.

Joachim Kugler assessed and extracted trial and outcome data, assessed the methodological quality of selected trials, contributed to the interpretation of the data, and contributed to and approved the final manuscript of the review.

Bernhard Elsner searched electronic databases and conference proceedings, screened titles and abstracts of publications identified by the search, selected and assessed trials, extracted trial data, guided the analysis and the interpretation of the data, and contributed to and approved the final manuscript of the review.

DECLARATIONS OF INTEREST

Jan Mehrholz: was a coauthor of one included trial (Hesse 2005). He did not participant in the quality assessment or data extraction of this study.
Marcus Pohl: was a coauthor of one included trial (Hesse 2005). He did not participant in the quality assessment or data extraction of this study.
Thomas Platz: none known.
Joachim Kugler: none known.
Bernhard Elsner: none known.

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Internal sources

- Wissenschaftliches Institut, Klinik Bavaria Kreischa, Germany.
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- SRH Fachhochschule für Gesundheit Gera gGmbH, Germany.

External sources

- No sources of support supplied

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

In our protocol we stated that we would use the PEDro scale to assess the methodological quality of the included trials. However, in Chapter 8 of the latest edition of the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2017), it is suggested that scales that yield a summary score should be avoided. We, therefore, have not used the PEDro scale to assess the methodological quality of the included trials, but used the Cochrane 'Risk of bias' tool instead.

In our protocol, we planned to quantify heterogeneity with the I^2 statistic and to use a cutoff of I^2 = 50% for all comparisons. Additonally, we planned to calculate the overall effects using a random-effects model instead of a fixed-effect model when we found substantial heterogeneity. However, in this update, we calculated the overall effects using a random-effects model regardless of the level of heterogeneity.

INDEX TERMS

Medical Subject Headings (MeSH)

*Activities of Daily Living; *Stroke Rehabilitation; Arm; Muscle Strength; Robotics; Stroke

MeSH check words

Humans