Assistive technology, including orthotic devices, for the management of contractures in adult stroke patients (Protocol)

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[Intervention Protocol]

Assistive technology, including orthotic devices, for the management of contractures in adult stroke patients

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ABSTRACT

This is the protocol for a review and there is no abstract. The objectives are as follows:

To assess the effects of assistive technologies for the management of contractures in people with stroke.

BACKGROUND

The management of long-term conditions is a national priority in England, Wales and Scotland. Approximately 110,000 strokes occur in England every year. Stroke is the single largest cause of adult disability. About 50% of stroke survivors are dependent on others for everyday activities (NAO 2005).

Stroke is defined by the World Health Organization as a clinical syndrome consisting of "rapidly developing clinical signs of focal (at times global) disturbance of cerebral function, lasting more than 24 hours or leading to death with no apparent cause other than that of vascular origin" (Hatano 1976). People with stroke often develop contractures due to paralysis and immobility (Duncan 1987). Contractures can be defined as a pathological condition resulting in stiffness associated with loss of elasticity and shortening of soft tissues (Harburn 1993). Consequences of contractures include reduced function, sleep disturbances, deformities, cosmetic problems, falls and pain. In addition to these there is also a cost burden in managing contractures in the form of increased drug and physical treatment (Sackley 2008).

Description of the condition

Contractures result in a loss of joint range of motion and exhibit increased stiffness usually associated with loss of elasticity and fixed shortening of the muscle, tendon, ligament, subcutaneous tissue and skin (Botte 1988; Harburn 1993). In a disuse model the contracture is normally associated with a reduction in muscle fibre length (this results from a reduction in the number of sarcomeres in series) and a loss in the extensibility of the collagenous structures (this results from collagen cross bridges that develop in an unloaded muscle) (Farmer 2001; Kwah 2012; Lieber 2010; O'Dwyer 1996).

Contractures were found in 60% of the 122 participants with stroke in a study by Sackley 2008 and over 50% in a study by

O'Dwyer 1996. Contractures were also reported in 55% of the elderly population in a study sample of 222 participants (Yip 1996). Neurological conditions, including stroke, are often accompanied by contractures affecting multiple joints (Farmer 2001). Contractures are also seen post surgically, post burns, in cranio-cerebral trauma, immobilisation, muscle weakness or paralysis and spasticity (Farmer 2001).

It is important to note that the increase in stiffness has often been inappropriately attributed to spasticity (Malhotra 2008), as spastic limbs may also exhibit an increased resistance to passive motion (Lance 1980). However, there is a need to treat these two as separate conditions. Contractures result from structural changes within the musculo-tendonous structures as a result of reduced use, disuse or a fixed positioning of the limb's segment in a shortened position. Spasticity normally occurs because of abnormal muscle activity that results from the disinhibition following a stroke (Malhotra 2008). Certain forms of spasticity can lead to a limb segment being held in a shortened position for prolonged durations and may therefore contribute to contracture formation (Malhotra 2008).

Measurement of a contracture

Contractures are characterised by the joint being held in a shortened position, a loss in the joint range of motion and an increase in the stiffness about a joint.

Passive goniometric measurements, where the force/moment used to produce the movement remain uncontrolled, have been the accepted method for measuring both the resting position of the joint and the loss in the passive range of motion about a joint. With improvements in technology these measurements of posture and passive range of motion are being taken under controlled conditions, i.e. conditions where the force/moment are concomitantly controlled or measured (Moseley 2008; Pandyan 2001).

Traditionally, the increases in stiffness were measured using subjective methods and clinical scales such as the Modified Ashworth scale (Bohannon 1987). However, when such measures have been used the increase in stiffness that is measured has always been attributed to an increase in spasticity as opposed to contractures (Pandyan 1999). More recently the increase in stiffness associated with contractures has been objectively measured using controlled torque/moment methods either indirectly (Lannin 2003) or directly (Malhotra 2008; Yeh 2005). These authors have all demonstrated that the increase in stiffness mainly arises as a result of contractures as opposed to spasticity (Ada 2006; Malhotra 2011; O'Dwyer 1996).

Various authors have attempted to identify a minimal clinically important difference (MCID) in passive range of motion in order to quantify contractures. Mehrholz 2005 described a 10 degree change as a MCID in passive range of motion. Wheatley-Smith 2012 suggested a 10% change in full normal range of motion as the MCID. Since quantifying improvement or deterioration of the upper limb, lower limb and individual joints has not yet been standardised in the literature, in this review we have used the Wheatley-Smith 2012 model of 10% MCID for all joints as the primary measure for contractures.

Description of the intervention

For the purpose of this review an assistive technology is defined as a mechanical, electrical or electromechanical device used to stretch or lengthen a muscle statically, dynamically or cyclically. It can be used as an adjunct to physical or occupational therapy to produce passive movement or stretch across a joint. The external force applied should strictly be non-manual (i.e. not passive movement from a therapist) but a force derived from the use of gravity and other physical principles. This force would be attempting to stretch or contract a muscle across one or more joints. There is evidence from well-conducted human and animal studies showing that appropriate applied stretching is effective in the management of contractures (Lieber 2010; Williams 1990). However, on the contrary, there is also evidence that certain methods of stretching are not more effective when compared with routine care.

Various assistive technologies, such as splinting (Lannin 2007), casting, orthosis, electrical stimulation (Pandyan 1997), cyclical or prolonged stretching (Harvey 2006), constant position or force (Yeh 2005), have been studied for the management of contractures in upper and lower limbs post stroke. Equipment used to position limb segments to maintain stretch (e.g. tilt table, standing frames) will be included as assistive technology; pillows, foam and sandbags, etc would not be considered as assistive technology. Commonly used assistive technologies are: neuromuscular electrical stimulation (NMES), continuous passive motion, tilt table, standing frame, splints (dynamic and static), serial casts, virtual reality, robotic arms, biofeedback, Lycra garments etc. Equipment that cannot be classified as assistive technology for this review includes: cycling (active), treadmill, hydrotherapy, botulinum toxin, mitt used for constraint-induced movement therapy, dressing and taping, etc.

How the intervention might work

For this review stretching is described as a constant force, variable force or a muscle contraction to produce a strain (change in length) in a muscle. This force can be applied manually or using a mechanical device. Stretch is known to produce viscous deformation of soft tissues when applied for 20 minutes or more (Duong 2001; Goldspink 1974). Equipment used to position limb segments to maintain stretch (e.g. tilt table, standing frames) will be included as assistive technology. However, pillows, foam sandbags etc will not be considered as assistive technology.

Contracture management uses one or more of the physiological effects of stretching:

- creep: e.g. some dynamic splints that take the joint to end range;
- stress relaxation: e.g. serial casting, repeated splinting;
- strengthening: e.g. NMES;
- mobilisation: e.g. NMES, continuous passive motion.

When a viscoelastic material is placed under a constant stress (force per unit area) there will be an increase in the strain (a ratio of change in length to original length), which is known as creep. It is therefore hypothesised that when a constant stretching moment is applied to a joint for a prolonged period of time there will be a concomitant increase in the strain within the soft tissue structures that cross a joint (e.g. Lieber 2010). After the source of stretch is removed there is some evidence that the increased strain will be lost (Petty 2001). This mechanism is expected to work when the muscle is stretched to end range and maintained in the end range. Assistive technologies rarely stretch muscles to end range during therapy. Dynamic splints use mechanisms of creep when the spring mechanism is fixed at maximum tension to stretch the muscle to end range.

When a viscoelastic material is placed under a constant strain there will be a decrease in the stress required to maintain the strain and this is called stress relaxation. Stress relaxation is hypothesised to occur when a joint is stretched and then held at a constant length (for example in a cast) for a prolonged period of time, i.e. the stress within the musculo-tendonous structures that are stretched will reduce. Once the cast is removed it is then further hypothesised an additional stretching force/moment being applied across the joint can be used to increase the strain within these structures. This is a method of sequential stretching in which the displacement is progressively increased by applying a quasi-static stretch. This mechanism will work for static/progressive splinting and serial casting. Thus, when the positioning constraint is removed, the structure can be moved into a new lengthened position before reapplying a positioning constraint to maintain this elongated position (Petty 2001).

Strengthening and mobilisation of a joint or muscle prevents loss of serial sarcomeres (that result from reduced use) and also prevents the formation of collagen cross bridges (that result from immobilisation of a joint) within the tendons of the muscles that cross a joint (Farmer 2001; Lieber 2010). Continuous passive motion acts by preventing collagen cross bridge formation but as the muscle is not active it may not be as efficient. Treatment with electrical stimulation works using both mechanisms. Muscle activity can maintain or strengthen a muscle, thereby preventing muscle atrophy that can contribute to reduced muscle length. Contractions in the antagonist muscle cause the stiff muscle to stretch, limiting the development of cross bridges within the intramuscular connective tissue. Muscle contractions also exert a force on the collagen realigning fibres in a stiff tendon, therefore preventing stiffness and contracture (Lieber 2010); for example, NMES works using these mechanisms and principles.

Why it is important to do this review

Contractures are found in almost 50% to 60% of the stroke population (O'Dwyer 1996; Sackley 2008). The presence of contractures could interfere with function, resulting in increased dependence and cost of care (Sackley 2008). It is important to prevent or manage contractures to provide patients with the maximal chance for recovery and regaining function. The Cochrane review of stretching (Katalinic 2010) does not address the issue of contracture prevention and the interventions included are not restricted to assistive technology alone. Katalinic 2010 included all interventions that aimed to maintain or increase the mobility of any synovial joint, whereas this review will be focused on assistive technologies, and the intervention is expected to influence the muscle tendon unit. Katalinic 2010 focused on treatments such as passive stretching, positioning, splinting and serial casting. Although this review will include splinting, positioning (using a mechanical device) and serial casting, other assistive technologies, such as neuromuscular electrical stimulation, robotics and virtual reality will also be included. Katalinic 2010 included neurological and some non-neurological adult and paediatric conditions, whereas the present review focuses specifically on an adult stroke population.

A Cochrane review of orthotic devices after stroke and non-progressive brain lesions has been withdrawn from publication following the identification of methodological flaws (Tyson 2009). Another review of physical treatment interventions for the management of spasticity after stroke (Monaghan 2011) suggests 'standing' to be effective treatment, but neither of these Cochrane reviews examine the effectiveness of assistive technology in contracture prevention or correction.

Splints are commonly used with one aim of preventing or treating contractures (Lannin 2003). Despite the lack of underpinning evidence various types of splinting are recommended, such as splinting in the submaximal stretched position and splinting in the functional position (Milazzo 1998). This highlights the fact that splinting in the fully stretched position has not been offered by therapists to patients, thereby depriving patients of a potentially effective treatment (Lannin 2011). The current review will try to bridge this gap in the literature.

Another important reason for doing this review is that the current literature does not differentiate between stretch used on a muscle crossing one joint and those crossing more than one joint and the effect of the intervention on these muscles. Our review will attempt to highlight this significant information from the included studies.

OBJECTIVES

To assess the effects of assistive technologies for the management of contractures in people with stroke.

METHODS

Criteria for considering studies for this review

Types of studies

We will include randomised controlled trials (RCT) where the primary objective of the studies was to treat, prevent or manage contractures. We will also include the first period of randomised controlled cross-over studies.

Types of participants

We will include studies of acute and chronic stroke patients aged 18 years and above, of both genders, and with no geographical restrictions. Stroke is defined by the World Health Organization as a clinical syndrome consisting of "rapidly developing clinical signs of focal (at times global) disturbance of cerebral function, lasting more than 24 hours or leading to death with no apparent cause other than that of vascular origin" (Hatano 1976).

Types of interventions

We will include studies of electrical, mechanical and electromechanical devices. We will not exclude studies on the basis of care or treatment providers: we will include studies where nurses, care workers, family members, physiotherapists or occupational therapists provided or helped the participant with self intervention. We will include studies that compare a pharmacological intervention plus assistive technology where there are two groups with a difference in treatment related to assistive technology.

We will also include studies where assistive technologies are used to provide stretch passively (such as splinting, positioning, casting etc) along with active assistive technologies (such as dynamic splinting, continuous passive motion, NMES etc). We will include assistive technology that is used to maintain stretched positions, such as tilt tables, whereas we will not consider pillows and sandbags as assistive technology.

Comparisons

We plan to carry out the following comparisons:

- assistive technology versus no treatment;
- assistive technology versus routine therapy;
- one assistive technology versus another assistive technology.

If possible we will explore outcomes immediately after the end of the intervention and at long-term follow-up (where data are available).

Types of outcome measures

The outcome measures in studies are likely to be a combination of levels of measurements. If levels of measurement are ratios or interval or ordinal level scales with levels greater than 30 units, we will use mean difference (MD) or standardised mean difference (SMD) to calculate the effect size. For all measures we will dichotomise outcome measures as appropriate (i.e. improvement versus no improvement) and then use odds ratios (OR) to quantify the likelihood of benefiting from treatment. In both situations we will report 95% confidence intervals.

Primary outcomes

- Passive range of motion: measured using goniometer with or without standardised force.
- Joint range of motion measured indirectly, for example by using finger palmar crease distance. We will base the definitions of lower and upper limit of range of motion for each joint on established textbooks (Magee 2006).

Secondary outcomes

Stiffness measured using standardised torque and the modified Ashworth Score (MAS). The MAS has traditionally been used to measure spasticity although there is uncertainty whether it measures stiffness of the muscle tendon unit rather than spasticity. Since active range of motion measures muscle strength and not stiffness of the muscle tendon unit, we will not include this as an outcome measure in the review. We will consider pain (visual analogue score (VAS), numerical scales), resting posture of limb (range of motion in degrees), improvement in function (Action Research Arm Test (ARAT), nine hole peg test, Functional Independence Measure-Functional Assessment Measure (FIM-FAM)), hygiene (finger palmar crease distance) and carer burden (VAS, carer strain index) as secondary outcomes. Many outcomes such as axillary or hand or perineal hygiene are quantified using range of motion of the corresponding joint(s) (Bhakta 2000).

Adverse events

We will consider the following as adverse events: pain associated with swelling, discomfort, skin breakdown, muscle tear, heterotopic ossification, dislocation or subluxation, drop-out from study and any other adverse events occurring as a result of experimental or control group treatment. We will also assess the safety of assistive technology with respect to the adverse events in the studies and we will record this in the data collection form.

Search methods for identification of studies

See the 'Specialized register' section in the Cochrane Stroke Group module. We will search for trials in all languages and arrange the

translation of relevant papers published in languages other than English.

Electronic searches

We will search the trials registers of the Cochrane Stroke Group and the Cochrane Musculoskeletal Group. In addition, we will search the following electronic bibliographic databases and trials registers:

- Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library*, latest issue);
- Database of Abstracts of Reviews of Effects (DARE) (*The Cochrane Library*, latest issue);
- Health Technology Assessment Database (HTA) (*The Cochrane Library*, latest issue);
- MEDLINE (EBSCO 1950 onwards) (Appendix 1);
- CINAHL (EBSCO 1982 onwards);
- EMBASE (Web of Science 1980 onwards);
- AMED (Allied and Complementary Medicine (from 1985);
- Science Citation Index (Web of Science 1970 onwards);
- PEDro (physiotherapy evidence database) (www.pedro.org.au/);
- REHABDATA (http://www.naric.com/?q=en/REHABDATA);
- RECAL Legacy Database (cdlr.strath.ac.uk/recal/);
- ClinicalTrials.gov (www.clinicaltrials.gov/);
- EU Clinical Trials Register (www.clinicaltrialsregister.eu);
- Stroke Trials Registry (www.strokecenter.org/trials/);
- Current Controlled Trials (www.controlled-trials.com);
- WHO International Clinical Trials Registry Platform (www.who.int/ictrp/en/);
- Australian New Zealand Clinical Trials Registry (www.anzctr.org.au/);
- UK Clinical Research Network Study Portfolio (http://public.ukcrn.org.uk/search/).

We developed the MEDLINE search strategy using a combination of controlled vocabulary and free-text terms with the help of the Cochrane Stroke Group Trials Search Co-ordinator and will adapt it for other databases.

Searching other resources

In an effort to identify further published, unpublished and ongoing trials we will:

- search the reference lists of included studies and other Cochrane and non-Cochrane reviews of similar topics;
- use Science Citation Index Cited Reference Search for forward tracking of important articles;
- contact authors active in the field;
- search for PhD and MSc theses.

Data collection and analysis

We will extract data from studies selected for inclusion using a data collection form prepared for this review. We will prepare a separate table of excluded studies to show all the available evidence relating to our research question.

We will collect information on participants, interventions, outcome measures, country of origin, etc. We will independently collect these items of data to avoid bias, and will meet at various stages to identify epidemiological, methodological and clinical differences and to reach consensus.

Where data are incomplete, we will contact the study authors for the missing information. We will import all data into RevMan 5.2 (RevMan 2012). We will carry out meta-analysis of extracted data to identify one or more interventions for the treatment of contractures.

Selection of studies

Two review authors (RAMM and VD) will screen the titles and abstracts of the records obtained from the searches of the electronic databases and exclude obviously irrelevant papers. We will obtain the full text of the remaining papers and three review authors (RAMM, PS, VD) will independently read the articles and shortlist studies to be included in the review. In the case of disagreement, a fourth review author (SF or ADP) will act as arbitrator to decide whether to include or exclude the disputed studies in the review. We will follow the PRISMA guidelines (Liberati 2009) and clearly document details of the search process at all stages.

Data extraction and management

The data collection form will have a separate data extraction section. We will enter the data from the included RCTs into this section. We will input descriptive statistics from the RCTs into RevMan 5.2 (RevMan 2012) for comparison.

Assessment of risk of bias in included studies

We will use The Cochrane Collaboration's 'Risk of bias' tool to extract information relating to validity in studies (Higgins 2011). We will pay particular attention to randomisation, concealment of allocation, and the presence of an independent blinded assessor and baseline similarity among participants. Studies that mention adverse effects, reasons for drop-outs and compliance in treatment and control groups separately will score higher on the 'Risk of bias' tool. We will weight the conclusions against the risks identified and effect sizes detected. Wherever there are disagreements between review authors on the presence of bias in included studies, two review authors (ADP and SF) will arbitrate to reach a conclusion.

Measures of treatment effect

The treatment effect will be measured using the odds ratio (OR), mean difference (MD) or standardised mean difference (SMD) depending upon the data available. Minimally important difference (MID) in degree of joint range of motion has been agreed as 10 degrees (Mehrholz 2005). Where possible we will split the outcome score dichotomously to be used for ORs. If not possible, we will use the MD between the control and intervention groups to calculate effect size. We will consider an OR of 1 as supporting the treatment group (if the effect was direction-dependant we will report this). We will consider an effect size of 0.3 and above as a good treatment effect (Domholdt 2005).

We will use the forest plots (with a summary effect) produced by RevMan 2012 to summarise various comparisons and investigate the effectiveness of one intervention over another. However, we will describe the treatment effect in consideration with other parameters including sample size, baseline similarity among participants, ease of use of the intervention, characteristics of the outcome measure used and adverse reactions.

For dichotomous outcomes we will use ORs and risk ratios (RRs) for sensitivity analysis, and for continuous data we will use SMD for variety of studies or MD for individual studies. We will report the outcomes using a random-effects model and 95% CIs.

Unit of analysis issues

We will treat joint range of motion in degrees from various joints in each individual as coming from an individual and therefore the unit of analysis would be the individual participant. The MCID is assumed as 10% change of total normal range of motion for each joint and we would generalise this to all joints studied.

Dealing with missing data

Where data are missing, we will contact the study authors for the original data. If appropriate, we will use methods of imputation to fill in the missing values and will describe the methods used within the review. We will consider the following methods of imputation:

- use of a mean of two data points to estimate a missing midpoint value;
- carry forward the last value when a midpoint mean cannot be calculated.

It is unlikely that we will use statistical methods for regression to impute missing values as many of the outcome measures have an ordinal level of measurement or constraints on maximum values (e.g. maximum range of active extension movement in the wrist cannot exceed 160 degrees when measured from full flexion).

Assessment of heterogeneity

Heterogeneity can result from methodological variation (either in treatment methods or in experimental design) and variations in response to treatment. We will use data collection forms to extract data related to methodological variations and will present these data in a tabular format. We will use this information to inform the subgroup analyses where appropriate. We will report variations in response to treatment using the I^2 value.

Assessment of reporting biases

The search criteria are sufficiently broad to ensure that all relevant studies, both published and unpublished, will be identified. We will assess all included studies for risk of bias and will tabulate and report the findings. We will use a funnel plot of effect size against the inverse of the standard error (1/SE) to confirm the presence or absence of bias (Higgins 2011).

Data synthesis

We will synthesise data using effect size and ORs, calculated using RevMan 5.2 (RevMan 2012). We propose to use a random-effects model for our analysis, as this is a more conservative estimate, and we will also report the corresponding I^2 value. If the result contains multiple small sample studies, we will use a random-effects model over the fixed-effect model for data synthesis .

Subgroup analysis and investigation of heterogeneity

If the data are available we will conduct the following subgroups analyses to explore if effect sizes vary with:

- joints treated (ankle, knee, hip, wrist and fingers, elbow and shoulder);
- time post stroke (acute (less than one month post stroke), subacute (between one and six months post stroke) and chronic (more than six months after stroke));
- type of assistive technology used (passive versus active, physiological mechanisms underpinning treatment);
- aims of treatment (prevention of contracture formation versus correction of established contractures);
- length of treatment period or dose of treatment (based on descriptions provided, we will divide trials into those providing low, medium or high doses of treatment).

One published Cochrane review (Katalinic 2010) includes splinting, which is relevant to our topic. We are of the view that the Katalinic 2010 review included studies where the physiology behind stretching was not according to first principles, i.e. creep, stress relaxation and strengthening and mobilisation. During meta-analysis of our data we expect to analyse the subgroup of studies that do not follow the above-mentioned principles. We will check for similarities between studies identified by Katalinic 2010 and the subgroup identified by us.

Sensitivity analysis

We will carry out a sensitivity analysis by excluding studies that have a high risk of bias. We will classify a study as having a high risk of bias if the following criteria are not met:

- lack of concealed random allocation;
- studies that do not have an independent assessor;
- studies in which there are differences between groups in terms of prognostic markers at baseline assessment.

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* *Indicates the major publication for the study*

APPENDICES

Appendix 1. MEDLINE search strategy

MEDLINE (Ovid) search strategy

1. cerebrovascular disorders/ or exp basal ganglia cerebrovascular disease/ or exp brain ischemia/ or exp carotid artery diseases/ or exp intracranial arterial diseases/ or exp "intracranial embolism and thrombosis"/ or exp intracranial hemorrhages/ or stroke/ or exp brain infarction/ or stroke, lacunar/
2. brain injuries/ or brain injury, chronic/
3. (stroke$ or cva or poststroke or post-stroke or cerebrovasc$ or cerebral vascular).tw.
4. ((cerebral or cerebellar or brain$ or vertebrobasilar) adj5 (infarct$ or isch?emi$ or thrombo$ or emboli$ or apoplexy)).tw.
5. ((cerebral or brain or subarachnoid) adj5 (haemorrhage or hemorrhage or haematoma or hematoma or bleed$)).tw.
6. exp hemiplegia/ or exp paresis/
7. (hempar$ or paretic or paresis or hemipleg$ or brain injur$).tw.
8. Gait Disorders, Neurologic/
9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
10. exp Upper Extremity/
11. (upper limb$ or upper extremit$ or arm or shoulder or hand or axilla or elbow$ or forearm$ or finger$ or wrist$).tw.
12. exp Lower Extremity/
13. (lower limb$ or lower extremit$ or buttock$ or foot or feet or hip or hips or knee or knees or leg or legs or thigh$ or ankle$ or heel$ or toe or toes).tw.
14. 10 or 11 or 12 or 13
15. exp Contracture/
16. (contracture or contractures).tw.
17. muscle rigidity/ or elasticity/
18. exp "Range of Motion, Articular"/
19. (range of movement or range of motion or ROM or (joint adj3 movement)).tw.
20. ((loss or lose or reduc$) adj3 elasticity).tw.
21. ((loss or lose or reduc$) adj3 muscle$ adj3 fibre$ adj3 length).tw.
22. ((shorten$ or stiff or stiffness or elastic$ or movement or rigid$ or extensib$ or flexib$ or tight or tightness) adj5 (joint or joints or musc$ or ligament$ or tendon$ or soft tissue)).tw.

23. 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22
24. physical therapy modalities/ or electric stimulation therapy/ or transcutaneous electric nerve stimulation/ or musculoskeletal manipulations/ or manipulation, orthopedic/ or motion therapy, continuous passive/
25. exp orthotic devices/ or self-help devices/
26. muscle stretching exercises/ or movement/ or posture/ or patient positioning/
27. splints/ or braces/ or electrical stimulation/ or robotics/
28. (assist$ adj5 (technolog$ or equipment or device$)).tw.
29. ((mechanical or electromechanical or electro-mechanical) adj5 (device or equipment)).tw.
30. ((mechanical or electric$ or electromechanical or electro-mechanical or manual or passive or self$ or auto$) adj5 stretch$).tw.
31. (splint or splints or splinting or cast or casts or casting or brace or braces or ortho$ or tilt table$ or tilt-table$ or standing frame$ or lycra).tw.
32. ((electric$ or magnetic or cortical) adj5 stimulat$).tw.
33. interferential therapy.tw.
34. (FES or TMS or rTMS or TENS or IFT).tw.
35. (robot$ or virtual reality or feedback or biofeedback or vibrat$).tw.
36. ((continuous passive adj3 (movement$ or motion$)) or CPM).tw.
37. (postur$ or position$).tw.
38. ((musculoskeletal or joint$) adj3 manipulat$).tw.
39. or/24-38
40. 9 and 14 and 23 and 39
41. exp animals/ not humans.sh.
42. 40 not 41

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V Durairaj and RA Mohammed Meeran developed the proposal with input from SE Farmer. P Sekaran, V Durairaj and RA Mohammed Meeran will read and select articles, and extract data for the review with help from SE Farmer. Prof. AD Pandyan will supervise the overall project.

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