Introduction

Inferior glenohumeral joint displacement, generally referred to as shoulder subluxation, is one of the most common secondary musculoskeletal impairments in the upper limb after stroke. The incidence in the period soon after stroke ranges from 7% to 81% and this variation appears to be related to the degree of paralysis of the muscles in the upper limb. For example, Najenson et al (1971) reported an 81% incidence, Smith et al (1982) reported a 60% incidence and Miglietta et al (1959) reported a 56% incidence in stroke patients who had no active motion at the shoulder. The incidence was lower (40%) in stroke patients who had some activity in their upper arm (Linn et al 1999). Similarly, Chaco and Wolf (1971) and Hurd et al (1974) reported only a 15% and 7% incidence respectively, in stroke patients who had activity of the upper limb muscles within one month.

Shoulder subluxation is considered to be a problem because it causes shoulder pain and hinders the recovery of upper limb function. It has been suggested that subluxation causes shoulder pain by overstretching the soft tissues (such as the capsule, ligaments and muscles) surrounding the shoulder (eg Cailliet 1980, Chino 1981, Shai et al 1984). However, most studies report no significant correlation between subluxation and pain (Bohannon and Andrews 1990, van Langenberghe and Hogan 1988, Zorowitz et al 1996). It is now thought that subluxation is only one of several factors that can cause shoulder pain after stroke. On the other hand, there is evidence to suggest that shoulder subluxation is associated with poor upper limb function (Hanger et al 2000) and reflex sympathetic dystrophy (Dursun et al 2000). Therefore, its prevention should be an important part of upper limb rehabilitation.

After stroke, as a result of paralysis, the gravitational pull on the humerus causes stretching of the capsule of the shoulder joint, resulting in inferior subluxation. Electromyographic studies show that the supraspinatus muscle and to a lesser extent the posterior deltoid muscle are key components in counteracting this downward pull (Basmajian and Bazant 1959, Chaco and Wolf 1971). Recently, electrical stimulation has been applied to these muscles (Baker and Parker 1986, Chae et al 2001, Chantraine et al 1999, Faghri et al 1994, Kobayashi et al 1999, Linn et al 1999, Mackenzie-Knapp 1999, Wang et al 2000, Yu et al 2001) in an effort to treat shoulder subluxation. There have been some narrative reviews of the efficacy of electrical stimulation in individuals after stroke (Binder-Macleod and Lee 1997, Chae and Yu 2000, Kimberley and Carey 2002, Morley et al 2002) and one systematic review investigating the effect of surface electrical stimulation on pain (Price and Pandyan 2001a and 2001b). The systematic review by Price and Pandyan investigated subluxation as a secondary outcome measure, and a motor response from the electrical stimulation was therefore not part of inclusion criteria. If the aim is to prevent subluxation, it is important that the electrical...
stimulation produces a motor response in the supraspinatus and the posterior deltoids muscles, since these muscles have been shown to be important in maintaining normal glenohumeral alignment (Basmajian and Bazant 1959, Chaco and Wolf 1971).

Therefore, we conducted a meta-analysis with the primary purpose of examining the efficacy of surface electrical stimulation which produced a motor response in the supraspinatus and/or posterior deltoid muscles in (i) preventing and (ii) reducing subluxation of the shoulder. The secondary purpose was to examine the efficacy of surface electrical stimulation in (i) improving function of the shoulder early after stroke and (ii) late after stroke. The tertiary purpose was to examine the efficacy of surface electrical stimulation in (i) preventing and (ii) reducing pain in the shoulder.

Methods

Identification and inclusion of trials Computerised bibliographic databases: MEDLINE (1966-2002), CINAHL (1982-2002), AMED (1985-2002), EMBASE (1974-2002) and the Cochrane Controlled Trials Register (Cochrane Library Issue 2, 2002) were searched from the first available year up until July 2002. Searches were performed using key words (MeSH) related to stroke, electrical stimulation and shoulder disorders, without language restrictions. Relevant studies were identified from titles and abstracts (where available) by one reviewer and full paper copies were obtained. Additional studies were identified from reference lists of the relevant trials and by hand searching of relevant conference proceedings.

To determine whether a trial should be included, two reviewers independently used predetermined criteria. These criteria were that: the trial was randomised or quasi-randomised; participants had a clinical diagnosis of stroke (with or without a CT scan); the average age of participants was more than 50 years; intervention was surface electrical stimulation; the stimulation frequency used was greater than 30 Hz, or it was otherwise reported that a motor response was obtained; and subluxation or pain or function was measured as an outcome. There was no exclusion on the basis of previous stroke but studies that included participants with other neurological conditions were omitted. Studies in which electrical stimulation was only one part of a multiple intervention were also excluded. Blinding of the assessor was recorded but was not a criteria for inclusion.

To be included, both reviewers had to agree that the trials met these criteria. Disagreements about the inclusion of trials were resolved by discussion. Included trials were then categorised as either (i) early electrical stimulation or (ii) late electrical stimulation. Trials that included participants with a stroke less than two months before being admitted into the study were categorised as early electrical stimulation and trials that included participants who had had a stroke more than two months before being admitted into the study were categorised as late electrical stimulation.

Similarity of inclusion criteria, sample characteristics, intervention, outcome measures between trials Two reviewers independently extracted details such as inclusion criteria, sample characteristics, intervention and outcome measures. Similarity of these aspects between the included trials was examined by two reviewers.

<table>
<thead>
<tr>
<th>Study</th>
<th>Inclusion criteria</th>
<th>Comments</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RCT/ Quasi RCT</td>
<td>Stroke</td>
<td>Age</td>
</tr>
<tr>
<td></td>
<td></td>
<td>only</td>
<td>&gt;50 years</td>
</tr>
<tr>
<td></td>
<td>✔✔✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Baker and Parker 1986</td>
<td>✗</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Chae et al 2001</td>
<td>✗</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Chantraine et al 1999</td>
<td>✔</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Faghri et al 1994</td>
<td>✔</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Kobayashi et al 1999</td>
<td>✔</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Leandri et al 1990</td>
<td>✗</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Linn et al 1999</td>
<td>✗</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Mackenzie-Knapp 1999</td>
<td>✗</td>
<td>✔</td>
<td>✗</td>
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<tr>
<td>Sonde et al 1998</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Wang et al 2000</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Wang et al 2002</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Yu et al 2001</td>
<td>✗</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

✔ = meets inclusion criteria, ✗ = does not meet inclusion criteria. RCT, randomised controlled trial. ES, electrical stimulation. I, inclusion. E, exclusion.
Table 2. Characteristics of included trials.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality (PEDro score)</td>
<td>4/10</td>
<td>5/10*</td>
<td>4/10</td>
<td>9/10*</td>
<td>5/10</td>
</tr>
<tr>
<td>Design</td>
<td>Parallel group design</td>
<td>Parallel group design</td>
<td>Parallel group design</td>
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</tr>
<tr>
<td></td>
<td>Randomised</td>
<td>Randomised</td>
<td>Quasi-randomised</td>
<td>Randomised</td>
<td>Randomised</td>
</tr>
<tr>
<td></td>
<td>Concealment: unknown</td>
<td>Concealed</td>
<td>Concealed</td>
<td>Concealed</td>
<td>unknown</td>
</tr>
<tr>
<td></td>
<td>C: Conventional hemi-sling, wheelchair arm support</td>
<td>C: Conventional therapy</td>
<td>C: Neuro-muscular facilitation, joint mobilisation, stretching</td>
<td>C: Conventional PT and OT</td>
<td>C: Conventional therapy</td>
</tr>
<tr>
<td>Inclusion criteria</td>
<td>Subluxation</td>
<td>Shoulder muscle paralysis</td>
<td>Subluxation</td>
<td>Manual muscle test for upper limb ≤ 2, reasonable communication ability</td>
<td>Subluxation</td>
</tr>
<tr>
<td>Sample characteristics</td>
<td>Average age: Exp/C = 56/55 yr</td>
<td>Average age: Exp/C = 65/69 yr</td>
<td>Average age: Exp/C (Kobayashi-D) = 69/53 yr (Kobayashi-S) = 59/53 yr</td>
<td>Average age: Exp/C = 71/73 yr</td>
<td>Average age: Exp/C (Wang-E) = 56/56 yr (Wang-L) = 58/58 yr</td>
</tr>
<tr>
<td></td>
<td>Average time after stroke: Exp/C = 49/46 days N = 63, M/F = 31/32, R/L = 29/34</td>
<td>Average time after stroke: Exp/C = 16/17 days N = 26, M/F = 15/11, R/L = 9/17</td>
<td>Average time after stroke: Exp/C (Kobayashi-D) = 95/190, (Kobayashi-S) = 60/190 days N = 22, M/F = 20/2, R/L = 12/10</td>
<td>Average time after stroke: Exp/C = 2/2 days N = 40, M/F = 18/22, R/L = 9/31</td>
<td>Average time after stroke: Exp/C(Wang-E) = 16/15, (Wang-L) = 427/434 days N = 32, M/F = 16/16, R/L = 15/17</td>
</tr>
<tr>
<td></td>
<td>Treatment time: increased from 0.5-7 hr/session, 1-3 session/d, 5 d/wk, 6 wk</td>
<td>Treatment time: increased from 1.5-6 hr/session, 1 session/d, 7 d/wk, 6 wk</td>
<td>Treatment time: 15 min/session, 2 session/d, 5 d/wk, 6 wk</td>
<td>Treatment time: increased from 0.5-1 hr/session, 4 session/d, 7 d/wk, 4 wk</td>
<td>Treatment time: increased from 0.5-6 hr/session, 3-1 session/d, 5 d/wk, 6 wk</td>
</tr>
<tr>
<td>Application of electrical stimulation</td>
<td>Electrical stimulation: 12-25 Hz (tetanised muscle contraction), electrodes placed on supraspinatus and deltoid muscles</td>
<td>Electrical stimulation: 35 Hz, electrodes placed on supraspinatus and deltoid muscles</td>
<td>Electrical stimulation: 20 Hz (strong contraction, sufficient to reduce subluxation which was confirmed by x-ray) Note: 2 treatment groups; deltoid and supraspinatus</td>
<td>Electrical stimulation: 30 Hz, electrodes placed on supraspinous fossa and posterior aspect of upper arm</td>
<td>Electrical stimulation: 10-24 Hz (tetanised muscle contraction), electrodes placed on supraspinatus and posterior deltoid</td>
</tr>
</tbody>
</table>
## Outcome measures

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subluxation:</strong> in mm (compared both sides), method: unknown</td>
<td>Subluxation: in mm (compared both sides), vertical distance from most inferior and lateral point on acromial surface of the acromioclavicular joint to the central point of the humeral head</td>
<td>Subluxation: in mm (compared both sides), vertical distance from inferior border of glenoid fossa to inferior line through anatomical neck of humeral head</td>
<td>Subluxation: grading 0-4 and in mm (only affected side), vertical distance from mid-point of glenoid fossa to the most superior aspect of head of humerus</td>
<td>Note: smaller number = larger subluxation</td>
<td></td>
</tr>
<tr>
<td><strong>Pain:</strong> subjective self report, request for analgesic drug</td>
<td>Pain: pain-free range of passive external rotation of the shoulder (compared both sides)</td>
<td>Pain: VAS (15 cm scale) on active shoulder abduction</td>
<td>Pain: pain-free range of active external rotation of shoulder of the affected side, and grading verbal scale from none (0) to severe (4)</td>
<td>Pain: pain-free range of active external rotation of shoulder of the affected side</td>
<td></td>
</tr>
<tr>
<td><strong>Arm function:</strong> nil</td>
<td>Arm function: Bobath assessment chart, EMG of posterior deltoid</td>
<td>Arm function: max isometric abduction contraction</td>
<td>Arm function: MAS (upper arm part)</td>
<td>Arm function: Fugl-Meyer</td>
<td></td>
</tr>
<tr>
<td><strong>Time of measurement:</strong> before, after 6 wk of treatment, 3 month F/U</td>
<td>Time of measurement: before, after 6 wk of treatment, 6 wk F/U</td>
<td>Time of measurement: before, after 6 wk of treatment, No F/U</td>
<td>Time of measurement: before, after 4 wk of treatment, 8 wk F/U</td>
<td>Time of measurement: before, after each 6 wk phase, 6 wk F/U</td>
<td></td>
</tr>
<tr>
<td><strong>Assessor:</strong> one of two was blinded</td>
<td>Assessor: blinded</td>
<td>Assessor: blinding uncertain</td>
<td>Assessor: blinded</td>
<td>Assessor: blinded</td>
<td></td>
</tr>
</tbody>
</table>

Exp = experimental group, C = control group, PT = physiotherapy, OT = occupational therapy, mm = millimetres, N = number of subjects, M = male, F = female, R = right side hemiplegia, L = left side hemiplegia, F/U = follow up. VAS, visual analogue scale. MAS, motor assessment scale.

*These scores are higher than those recorded on PEDro because additional information was obtained from the authors.

### Quality of trials

One reviewer assessed the methodological quality of included trials using the PEDro scale (Moseley et al 2002), which is based on the Delphi List (Verhagen 1998) and available at the Centre for Evidence-Based Physiotherapy website (http://ptwww.cchs.usyd.edu.au/pedro/scaleitems). The scale assesses: specification of eligibility criteria; random allocation to groups; concealed allocation; groups similar at baseline; blinding of subjects, therapists and assessors; outcome measurements obtained from more than 85% of subjects; statistical comparisons between groups; and reporting of point measures and measures of variability.

### Analysis of data

Number of participants, means and standard deviations of outcome measures were extracted. Where data were not available in the published studies, details were requested from the first-named or corresponding author. Where raw data were available, means and SDs of change scores were calculated. Otherwise, means and standard deviations of post-intervention data were used. If standard deviations were not available, they were calculated from the standard errors. Where standard errors could only be determined from published graphs, the average value from three estimators was used.
Trials using similar methods of measurement for the primary outcome of subluxation or the secondary outcome of function or the tertiary outcome of pain at similar times post-intervention were considered for pooling. Then the data were entered into the Cochrane Collaboration's Review Manager software program (RevMan 4.1) and pooling was carried out. Where the same methods of measurement were used, the effect sizes were reported as weighted mean differences and 95% CI, and a fixed effects model was used. Where different methods of measurement were used, the effect size was reported as standardised mean differences and 95% CI, and a random effects model was used. A test of heterogeneity of the data was performed and if significant ($p < 0.1$ using the Q statistic) the source of heterogeneity was investigated by doing a sensitivity analysis.

Results

Identification and selection of trials  Sixty-seven references were retrieved from the search strategy. Eighteen relevant studies were identified; however, six of these 18 studies were reviews rather than experiments. Therefore, 12 studies were assessed for inclusion (Table 1). Studies were excluded because: they were not randomised or quasi-randomised trials (Chae et al 2001, Mackenzie-Knapp 1999); they included participants suffering from both brain injury and stroke and separate data for stroke participants could not be obtained (Chantraine et al 1999); they included very young stroke subjects (Mackenzie-Knapp 1999); they used implanted electrodes (Chae et al 2001, Yu et al 2001); or they used non-motor parameters of electrical stimulation (Leandri et al 1990, Sonde et al 1998). Six studies met the inclusion criteria according to both reviewers. Two of these six (Wang et al 2000, Wang et al 2002) are reports of different outcome measures from the same intervention on the same subjects and were therefore considered as one study. However, they reported two categories of participants according to time after stroke and therefore were considered as two trials, an early electrical stimulation trial (Wang-E), and a late electrical stimulation trial (Wang-L). Another one of the six (Kobayashi et al 1999) was also separated into two trials according to whether the deltoid muscle was stimulated (Kobayashi-D) or the supraspinatus muscle (Kobayashi-S). Therefore, in total, data from seven individual trials were extracted. Additional information was obtained from Linn (unpublished data) and Faghri (assessor blinding). Four trials with 145 participants were categorised as early electrical stimulation trials (Baker and Parker 1986, Faghri et al 1994, Linn et al 1999, Wang-E) and three trials with 38 participants were categorised as late electrical stimulation trials (Kobayashi-D, Kobayashi-S, Wang-L).

Similarity of inclusion criteria, sample characteristics, intervention and outcome measures between trials  The inclusion criteria were slightly dissimilar across the early trials (Table 2). Two of the trials (Baker and Wang-E) selected subjects who already had shoulder subluxation before being admitted into the trial, whereas the other two (Linn and Faghri) selected subjects who had very little muscle activity around the shoulder (and who therefore may or may not have already had subluxation). All of the late electrical stimulation trials selected subjects who had subluxation (Table 2).

The sample characteristics were similar across all trials (Table 2). Across the early electrical stimulation trials, the age ranged from 55 to 73 years old. Time after stroke before being admitted to the trial ranged from 2 to 49 days with about half of the participants (49%, 79), having an average admission time of less than 17 days after stroke. In the other 43%, the average admission time after stroke was 46 days in the control group and 49 days in the experimental group (Baker). Gender distribution was almost equal (49% male, 51% female). However, the majority of participants (61%) had left side hemiplegia. This may have been because subjects in one trial had to have reasonable communication and this would bias selection towards left hemiplegia (Linn). Across the late electrical stimulation trials, the average age ranged from 53 to 69 years old, and time after stroke before being admitted into trials ranged from 60 to 434 days. Seventy-six per cent of participants were male. Distribution between right and left side hemiplegia was not very different (47% had right hemiplegia).

All trials used electrical stimulation as an adjunct to conventional therapy (ie electrical stimulation plus conventional therapy was compared with conventional therapy). The application of electrical stimulation was similar across trials (Table 2). Across the early electrical stimulation trials, intervention was carried out over 4-6 weeks, 5-7 days/week. The duration of electrical stimulation was increased over time from between 1.5 and 2 hr/day to between 4 and 6 hr/day. Across the late electrical stimulation trials, intervention was carried out over six weeks, 5 days/week. The duration of electrical stimulation was increased over time from between 0.2 and 1.5 hr/day to between 0.5 and 6 hr/day. All trials applied electrical stimulation to supraspinatus and/or deltoid muscles. Most of the trials used stimulation frequencies greater than 30 Hz and all trials reported that the stimulation produced muscle contraction. All trials reported progressing the application of electrical stimulation by systematically increasing both the duration and duty cycle (ON:OFF) when subjects were able to complete a session without fatigue of the stimulated muscle(s). However, conventional therapy was not consistent across trials (Table 2) and there was not enough detail to judge whether differences would affect the outcome.

The method of measurement was similar across trials for subluxation but more varied for function and pain (Table 2). Subluxation was measured in millimetres from plain antero-posterior x-rays of the shoulder in all seven trials. Four trials measured subluxation by comparing the affected side with the unaffected side while three trials measured the affected side. Function was variously represented by measures of strength (Kobayashi-D,
### Table 1: Weighted Mean Difference (WMD) for Subluxation of the Shoulder After Stroke

<table>
<thead>
<tr>
<th>Study</th>
<th>Early ES+CT</th>
<th>Early CT</th>
<th>WMD</th>
<th>Weight</th>
<th>WMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baker</td>
<td>31</td>
<td>-8.6 (4.9)</td>
<td>32</td>
<td>-13.3 (7.9)</td>
<td>42.2</td>
</tr>
<tr>
<td>Faghri</td>
<td>13</td>
<td>-2.5 (3.2)</td>
<td>13</td>
<td>-9.9 (6.4)</td>
<td>29.8</td>
</tr>
<tr>
<td>Linn</td>
<td>19</td>
<td>-26.2 (5.6)</td>
<td>20</td>
<td>-31.3 (11.7)</td>
<td>13.5</td>
</tr>
<tr>
<td>Wang-E</td>
<td>8</td>
<td>-13.0 (2.7)</td>
<td>8</td>
<td>-24.0 (7.5)</td>
<td>14.6</td>
</tr>
<tr>
<td>Total</td>
<td>(95% CI) 71</td>
<td>73</td>
<td></td>
<td>100.00</td>
<td>6.5 [4.4, 8.6]</td>
</tr>
</tbody>
</table>

### Table 2: Weighted Mean Difference (WMD) for Subluxation of the Shoulder After Stroke

<table>
<thead>
<tr>
<th>Study</th>
<th>Late ES+CT</th>
<th>Late CT</th>
<th>WMD</th>
<th>Weight</th>
<th>WMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kobayashi-D</td>
<td>6</td>
<td>-7.2 (7.3)</td>
<td>5</td>
<td>-7.4 (8.2)</td>
<td>20.3</td>
</tr>
<tr>
<td>Kobayashi-S</td>
<td>6</td>
<td>-5.8 (5.4)</td>
<td>5</td>
<td>-7.4 (8.2)</td>
<td>24.8</td>
</tr>
<tr>
<td>Wang-L</td>
<td>8</td>
<td>-24.0 (5.5)</td>
<td>8</td>
<td>-26.7 (6.0)</td>
<td>54.8</td>
</tr>
<tr>
<td>Total</td>
<td>(95% CI) 20</td>
<td>18</td>
<td></td>
<td>100.00</td>
<td>1.9 [-2.3, 6.1]</td>
</tr>
</tbody>
</table>

#### Figure 1. Examination of the efficacy of a) early electrical stimulation in the prevention of subluxation by pooling post-intervention data from 4 trials, and b) late electrical stimulation in the reduction of subluxation by pooling post-intervention data from 3 trials that measured subluxation in millimetres from plain AP x-rays of the shoulder. ES, electrical stimulation. CT, conventional therapy. WMD, weighted mean difference.

### Quality of trials

Five trials were assessor-blinded, randomised controlled trials with baseline comparability between control and treatment groups. Two trials (Kobayashi-S, Kobayashi-D) were quasi-randomised and blinding was not reported. There was no report of the number of subjects who dropped out in any trial except for Linn. The mean PEDro score for the quality of the methods for the four early electrical stimulation trials was 5.8 (range 4-9) and for the three late electrical stimulation trials, 4.3 (range 4-5) out of a possible 10 points. (See Table 2 for PEDro score of individual trials.)
### Early ES+CT vs Early CT

<table>
<thead>
<tr>
<th>Study</th>
<th>n</th>
<th>mean (SD)</th>
<th>n</th>
<th>mean (SD)</th>
<th>WMD (95% CI Fixed)</th>
<th>Weight % (95% CI Random)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faghri</td>
<td>13</td>
<td>47.3 (45.6)</td>
<td>13</td>
<td>22.0 (36.0)</td>
<td></td>
<td>20.3 [6.3, 56.9]</td>
</tr>
<tr>
<td>Linn</td>
<td>20</td>
<td>42.2 (32.6)</td>
<td>20</td>
<td>41.5 (33.5)</td>
<td></td>
<td>31.4 [-19.8, 21.2]</td>
</tr>
<tr>
<td>Wang-E</td>
<td>8</td>
<td>60.0 (6.5)</td>
<td>8</td>
<td>32.7 (8.1)</td>
<td></td>
<td>48.3 [20.1, 34.5]</td>
</tr>
<tr>
<td>Total</td>
<td>41</td>
<td></td>
<td>41</td>
<td></td>
<td>100.00 [0.4, 36.7]</td>
<td></td>
</tr>
</tbody>
</table>

Test for heterogeneity chi-square = 5.77 df = 2 p = 0.06
Test for overall effect z = 2.00 p = 0.06

### Late ES+CT vs Late CT

<table>
<thead>
<tr>
<th>Study</th>
<th>n</th>
<th>mean (SD)</th>
<th>n</th>
<th>mean (SD)</th>
<th>WMD (95% CI Fixed)</th>
<th>Weight % (95% CI Fixed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kobayashi-D</td>
<td>6</td>
<td>22.6 (20.2)</td>
<td>5</td>
<td>11.5 (21.5)</td>
<td></td>
<td>63.5 [13.8, 35.9]</td>
</tr>
<tr>
<td>Kobayashi-S</td>
<td>6</td>
<td>31.7 (33.4)</td>
<td>5</td>
<td>11.5 (21.5)</td>
<td></td>
<td>36.5 [2.9, 52.9]</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td></td>
<td>10</td>
<td></td>
<td>100.00 [5.4, 34.2]</td>
<td></td>
</tr>
</tbody>
</table>

Test for heterogeneity chi-square = 0.19 df = 1 p = 0.66
Test for overall effect z = 1.43 p = 0.15

**Figure 2.** Examination of the efficacy of a) early electrical stimulation in improving early function of the shoulder by pooling normalised post-intervention data from 3 trials that measured upper limb function using scales and b) late electrical stimulation in improving late function of the shoulder by pooling change data from 2 trials that measured strength as maximum isometric abduction force in Newtons. ES, electrical stimulation. CT, conventional therapy. WMD, weighted mean difference.

The weighted difference between means suggests that late electrical stimulation plus conventional therapy only reduces subluxation of the shoulder after stroke by 1.9mm and the 95% CI (-2.3 to 6.1) indicates that there is no evidence that it is superior (p = 0.40) to late conventional therapy.

The effect on early upper limb function (Figure 2a) was examined by pooling post-intervention data from the three early electrical stimulation trials that measured function using upper limb scales (Faghri, Linn and Wang-E). The scales were the Bobath assessment chart (Faghri), MAS scale (Linn) and Fugl-Meyer (Wang-E). In order to compare the trials, scores were converted to a percentage. Because the scales were similar in concept but differed in the categories measured, a random effects model was used. The weighted difference between means suggests that early electrical stimulation plus conventional therapy is superior (p = 0.05) to early conventional therapy in increasing function by 19% (95% CI 0 to 37). The effect on late upper limb function (Figure 2b) was examined by pooling change data from two late electrical stimulation trials that isometric abduction strength in Newtons (Kobayashi-D, Kobayashi-S). The weighted difference between means suggests that late electrical stimulation plus conventional therapy increases abduction strength after stroke by 14.4 N but the 95% CI (-5.4 to 34.2) indicates that there is no evidence that it is superior (p = 0.15) to late conventional therapy.

The prevention of pain (Figure 3a) was examined by pooling post intervention data from two early electrical stimulation trials that measured pain-free passive shoulder external rotation (Faghri, Linn) and one early electrical stimulation trial that measured pain-free active shoulder external rotation (Wang-E) using goniometry. The weighted difference between means suggests that early
electrical stimulation plus conventional therapy only maintains 4 degrees of pain-free passive/active shoulder external rotation after stroke and the 95% CI (-1.2 to 8.6) indicates that there is no evidence that it is superior ($p = 0.14$) to early conventional therapy. The reduction of pain (Figure 3b) was examined by pooling change data from 2 trials that measured pain on a 15 cm VAS during active shoulder abduction. ES, electrical stimulation. CT, conventional therapy. WMD, weighted mean difference.

**Discussion**

This systematic review has demonstrated that there is evidence to support the efficacy of early electrical stimulation as an adjunct to conventional therapy for preventing shoulder subluxation and for increasing upper limb function, and of late electrical stimulation as an adjunct to conventional therapy in reducing pain.

Electromyographic studies show that supraspinatus and, to a lesser extent, posterior deltoid are key components in counteracting the inferior displacement of the glenohumeral joint (Basmajian and Bazant 1959, Chaco and Wolf 1971). Therefore, we included only trials that used stimulation frequencies greater than 30 Hz or
was a wide range between subjects, which meant that some
two months to differentiate between early and late trials. In

to separate the effect of electrical stimulation for
stimulation trials according to the average time after stroke
(subluxation (van Langenberghe and Hogan 1988). In this
(Figure 4) and corresponds to a Grade 1
the average height of the glenoid fossa (40mm)
least of
humeral head relative to the glenoid fossa is one sixth of
(Figure 4). Six-and-a-half millimetres of movement of the
significant treatment effect of this type of electrical
stimulation to ensure that muscle activity counteracted
otherwise reported a motor response to electrical
stimulation in order to counteract inferior displacement. Our findings indicate that there is a
significant treatment effect of this type of electrical
stimulation in preventing subluxation of about 6.5mm (Figure 4). Six-and-a-half millimetres of movement of the
humerus head relative to the glenoid fossa is one sixth of
the average height of the glenoid fossa (40mm)
(McPherson et al 1997) and corresponds to a Grade 1
subluxation (van Langenbergh and Hogan 1988). In this
review, we categorised trials into early and late electrical
stimulation trials according to the average time after stroke
to separate the effect of electrical stimulation for
prevention versus reduction. We somewhat arbitrarily used
two months to differentiate between early and late trials. In
one of the early trials (Baker), even though the average
admission time to the study was under two months, there
was a wide range between subjects, which meant that some
subjects were admitted later than two months. However,
the test for heterogeneity of trials was not significant. Even if
this trial is not excluded, there is prevention of a larger
amount of subluxation (weighted mean difference 7.8mm,
95% CI 5.0 to 10.5) suggesting that the finding is robust.

Our finding that electrical stimulation prevents subluxation
is in line with a previous review (Price and Pandyan 2001b)
that pooled analysed change data from two trials (Faghri et
al 1994 and Linn et al 1999). They reported a significant
(p < 0.001) treatment effect of electrical stimulation of 1.1
SD (95% CI 1.66 to 0.60). However Linn’s data is
published in centimetres and this has not been converted to
millimetres to be comparable with Faghri. Also, Faghri did
not publish standard deviations or standard errors of the
change scores and it appears that the authors have instead
used the average standard deviation of the pre- and post-
intervention scores. These procedures would have the effect
of reducing the effect size. In addition, our pooled analysis
includes four trials and this may explain why our finding is
larger and less variable.

In contrast, the evidence does not support the treatment
effect of late electrical stimulation or conventional therapy
in reducing shoulder subluxation. This reflects the common
clinical perception that it is not possible to reduce shoulder
subluxation once it has occurred.

Although the number of trials in this review is small, they
are of reasonable quality (6/10), which suggests that the
findings are believable and can be cautiously generalised.
In addition, the application of electrical stimulation was
similar across trials and can therefore be synthesised into a
protocol. Since subluxation is more related to lack of
muscle activity (Miglietta et al 1959, Najenson et al 1971,
Smith et al 1982) than the presence of pain (Bohannon and
Andrews 1990, van Langenbergh and Hogan 1988,
Zorowitz et al 1996), the criteria to apply electrical
stimulation should be loss of function as a result of
paralysis of shoulder muscles after stroke. Therefore, we
recommend that for those patients with a score on Item 6 of
the Motor Assessment Scale for stroke (Carr et al 1985) of
less than 4 early after stroke, electrical stimulation be
applied daily to the posterior deltoid and supraspinatus
muscles at more than 30 Hz, beginning at 1 hr/day,
progressing to 6 hr/day, and continuing until the score on
Item 6 of the Motor Assessment Scale reaches 4.

We were also interested in whether electrical stimulation
applied so that it produced a motor response resulted in an
increase in function and a decrease in pain. Our analysis
indicates that early electrical stimulation as an adjunct to
conventional therapy is superior to conventional therapy in
increasing function. Even though the test for heterogeneity
was not significant (p = 0.05), one trial (Wang-E) differed
from the other two due to its unusually small standard
deviations, so a sensitivity analysis was performed. When
this trial is removed from the analysis, there is no
significant effect of electrical stimulation plus
conventional therapy on function (8% weighted mean
difference, 95% CI -9.0 to 25), which is similar to the finding
of the previous review (Price and Pandyan 2001a and
2001b). In addition, there is a 14 N increase in isometric
abduction strength after late electrical stimulation.
However, this finding was not significant, possibly because
of small subject numbers. A previous meta-analysis on the
effect of electrical stimulation on strength after stroke
(Glanz et al 1996) has shown an increase in strength.

Finally, our analysis found no evidence that early electrical
stimulation as an adjunct to conventional therapy is
superior to conventional therapy in preventing pain.
However, pain was measured indirectly as “pain-free range
of shoulder external rotation”. When it was measured more
directly using a visual analogue scale, the application of
late electrical stimulation was more effective than
conventional therapy at reducing pain. These findings are
contrast with the previous review by Price and Pandyan
(2001a and 2001b). However, Price and Pandyan included
trials where the electrical stimulation produced a sensory
response (Leandri et al 1990, Sonde et al 1998) as well as
those that produced a motor response (Faghri et al 1994,
Linn et al 1999).

In conclusion, this systematic review has demonstrated that
early application of electrical stimulation applied in a way
that produces a motor response in deltoid and supraspinatus muscles is effective in preventing 6.5mm of shoulder subluxation. Therefore, electrical stimulation should be started as early as possible as part of best practice for those patients who are at risk of developing subluxation as a result of paralysis of shoulder muscles after stroke. This practice may also help to increase function and reduce another common secondary musculoskeletal side effect of stroke, shoulder pain.

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