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A pilot randomized controlled trial of a daily muscle stretch regime to prevent contractures in the arm after stroke

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Objective: To evaluate the feasibility and effects of daily stretch positioning for prevention of contractures in stroke patients without arm function.
Design: Randomized controlled pilot study.
Setting: Stroke rehabilitation ward, UK.
Subjects: Twenty-five subjects drawn from an initial pool of 126 presenting with loss of arm function, all within four weeks of stroke.
Interventions: In addition to usual care, subjects in the experimental group ($n = 13$) were prescribed two 30-min stretches for wrist and finger flexors and two 30-min stretches targeting shoulder adductors and internal rotators, per day for up to 12 weeks post stroke. Stretches were carried out by therapists and nursing staff.
Main measures: Passive range of wrist extension and shoulder external rotation to standard force or to pain at four, eight and twelve weeks after stroke.
Results: Compliance was variable. Frequency of positioning was fair from four to eight weeks post stroke but declined after that. Mean (SD) frequency of stretch positions completed between four and eight weeks was 36.5 (13.0) for the wrist, 31.2 (14.1) for the shoulder, out of 56 prescribed. There were no significant effects of treatment. By eight weeks post stroke the mean range of wrist extension and shoulder external rotation lost on the affected side in both groups was ~ 30 degrees.
Conclusions: The stretch treatment was not well tolerated over many weeks. Statistical power was low due to the large degree of variability of range of motion and small sample size. The regime tested cannot be recommended as a workable treatment to prevent contractures.

Introduction

Recovery of arm and hand movement after stroke can take many weeks.[1,2] While the arm is immobile, muscle stiffness and contractures frequently develop which can lead to pain and discomfort and inevitably compromises emergent recovery of movement. In severe cases the stiffness can make everyday activities such as dressing, washing and hand care difficult.

Contractures are recognized by a loss of range of motion and/or increased resistance to passive movement. This condition in stroke patients is often considered to be due to spasticity.[3,4] However a number of investigations of subjects with spasticity have confirmed that resistance to passive

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movement is also due to changes in mechanical properties of muscle.[5–7] Animal studies have shown that adaptations of muscle length and extensibility occur in response to immobilization and depend upon the position in which the muscle is immobilized. When a muscle is immobilized in a shortened position structural changes in contractile and connective tissue occur which result in the optimum tension being reset to the new shorter resting length.[8–11] These changes are evident in experimental animal models after four weeks of immobilization.[8]

During hospital admission, even to specialist stroke care wards, only a very small proportion of the subject's day is spent in therapy.[12,13] For most of the hours subjects sit with their affected hand resting on their laps or on pillows. Shoulder adductors and internal rotators, elbow flexors, wrist and long finger flexors are resting in shortened positions.[14] Consequently, in accordance with the animal models, structural changes in these muscles that increase tension at short lengths are likely to contribute to the muscle stiffness and contracture development that occurs in the early weeks after stroke.

It may be possible to prevent these changes using an arm stretching regime. Sustained stretch positions are recommended in some physiotherapy texts[14,15] but are not commonly used in the UK. A literature search found only one paper that reported evaluation of the use of sustained stretch positions for the arm after stroke.[16] The results were inconclusive.

This study had two aims: (1) To assess the feasibility of a daily arm positioning regime carried out by both therapists and nurses working on stroke rehabilitation wards. (2) To test the effectiveness of the regime for preventing the development of muscle stiffness and contractures in wrist and finger flexors and shoulder internal rotators in the early weeks after stroke.

Methods

Subjects

Twenty-nine subjects were recruited to the study. To be included, subjects had to be admitted to the stroke wards at North Bristol NHS Trust, have a primary diagnosis of first unilateral stroke, be within four weeks of onset and give informed consent. They also had to have lost function in the affected arm and hand. The criterion for this was the inability to pick up a polystyrene cup from a table with the affected hand. Subjects were excluded if they had arthritis or arm pain before the stroke, had poor comprehension, were in a confused state, had dementia or were medically unfit for the treatment.

The number of subjects considered for the study is shown in Figure 1. All the procedures were performed in accordance with a protocol approved by the Local Research Ethics Committees at North Bristol NHS Trust.

A randomized group design was used. A computer-generated sequence for group allocation was kept by a person who was independent of the recruitment process. Allocation was revealed after recruitment by a phone call to the study physiotherapist (EB) who then organized the appropriate treatment. Fourteen subjects were allocated to the experimental group and 15 to the control group. Unusually, subjects were allocated to group before the first measurement at four weeks post stroke. This was because it was considered important to begin the stretch positioning as early as possible after stroke and some subjects were unable to sit in a chair suitable for measurement at this time. Therefore it was decided to keep measurements related to time since stroke rather than to time since recruitment. Although this muddied the baseline a little (four subjects began the treatment before the first measure at four weeks), we considered that the control group data would be useful for describing the development of contractures in a typical stroke ward in the UK. Such data are sparse in the literature. Four subjects were lost to the study before outcome measurements at eight weeks post stroke. The characteristics of the remaining 25 are listed in Table 1.

Intervention

All subjects received the standard arm care currently practised on the wards. Standard care did not include sustained stretches. Outside of therapy sessions patients are advised to keep their arms supported on a Bexhill Arm Support[17] if they are seated in a wheelchair. The Bexhill Support is essentially a shelf that fits over the side of the wheelchair; it allows the affected arm to be

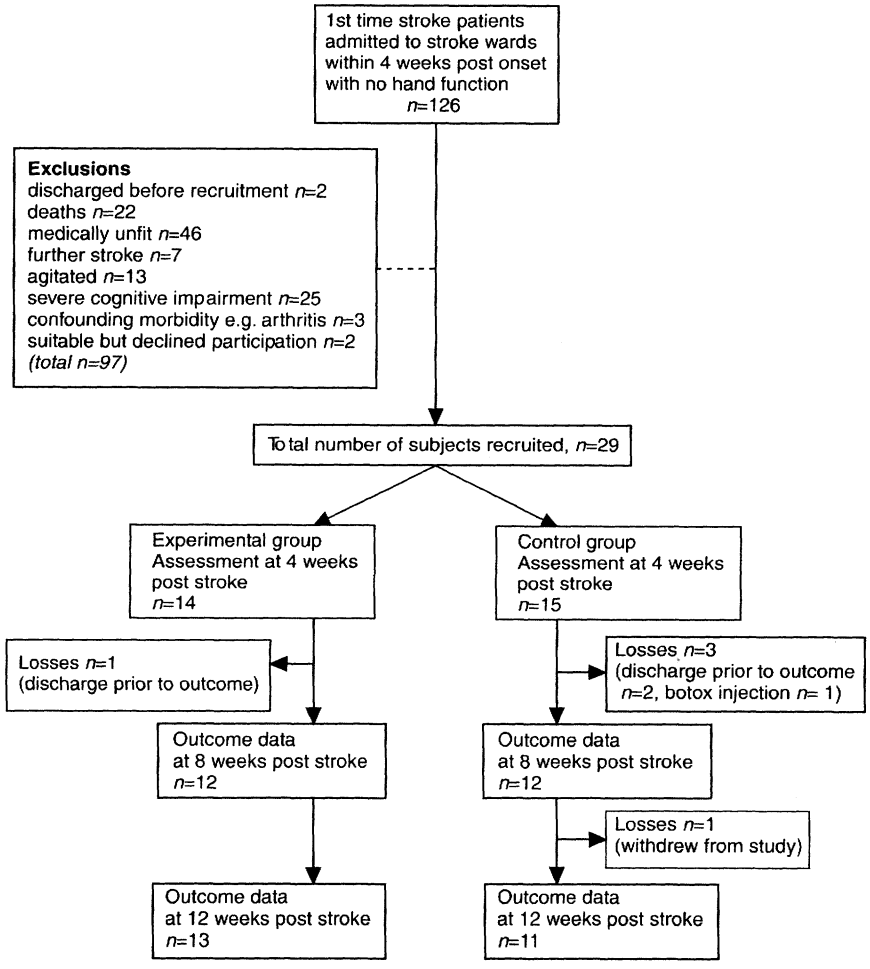

Figure 1 Study design. Thirteen experimental and 12 control subjects completed the study. Incomplete data: 12/13 subjects in the experimental group were measured at eight weeks, the remaining subject was unavailable for measurement due to illness; 11/12 subjects in the control group were measured at 12 weeks.

supported with the fingers extended and wrist in neutral position. Patients are encouraged to use a pillow for support when sitting in a bedside chair. In practice many sat with their hands on their laps (personal observations).

Subjects allocated to the experimental group were prescribed a daily stretch regime of two positions each to be carried out for two periods a day. One position was specifically designed to target wrist and finger flexors, the other simultaneously targeted shoulder adductors and internal rotators and biceps (see Figure 2). These muscle groups were considered to be particularly stiff in a survey of patients on the stroke wards that was conducted prior to the study. Stretches were targeted at muscle groups because there was not time to give each specific shoulder muscle a sustained stretch.

The wrist and finger flexors were stretched on a hinged board.[18] The angle of the wrist was set to give stretch but also to be considered tolerable for a sustained period. The shoulder position was taken from a physiotherapy text by Ada and Canning.[14] This position places the glenohumeral joint into some external rotation and was found to be more acceptable to elderly patients than

Table 1 Subjects' characteristics and range of active motion at four weeks post stroke

Subjects	Sex	Age	Range of active motion at 4 weeks	
			Wrist extension	Shoulder external rotation
Control group				
C1	M	51	0	0
C2	F	89	8	35
C3	M	52	0	0
C4	F	80	0	0
C5	F	79	12	24
C6	M	46	0	0
C7	F	82	0	0
C8	M	69	0	0
C9	M	67	0	0
C10	M	61	11	27
C11	M	53	0	0
C12	M	66	0	0
Mean		*66*	*2.6*	*7.2*
SD		*14*	*4.8*	*13.2*
Experimental group				
E1	M	63	0	0
E2	M	84	0	0
E3	F	78	0	34
E4	M	68	0	0
E5	M	55	0	0
E6	M	78	9	0
E7	F	76	0	0
E8	F	78	0	0
E9	M	74	23	20
E10	M	63	10	18
E11	M	61	0	8
E12	M	56	0	0
E13	F	79	0	0
Mean		*70*	*3.2*	*6.2*
SD		*10*	*6.9*	*11.0*

Note measurements started from neutral (0 = horizontal position) for the wrist and from mid position for the shoulder external rotation.

positions involving full range of external rotation (personal observations).

Subjects were to be put into each of these positions for two 30-min periods a day. There are no human studies on which to base a recommended 'dose' of stretch positioning. Experiments on neurologically intact mice have shown that 30 min stretch a day was enough to prevent loss of range of motion when a muscle was immobilized in a shortened position for the rest of the time.[19] Our regime of two 30-min stretches in each position was determined by reasoning that if two stretches were requested we were likely to achieve at least one occurrence of each stretch a day; if two were done then so much the better. More than four 30-min stretching periods a day was considered unworkable by the staff consulted. A pilot study of 10 stroke subjects all between two and six weeks of stroke who participated in this regime for five days indicated that this frequency of positioning was acceptable and caused little if any discomfort (unpublished observations).

Ward staff (nurses, occupational therapists and physiotherapists) were trained to put subjects' arms safely into specified positions. The time of start and end of each position was logged on a

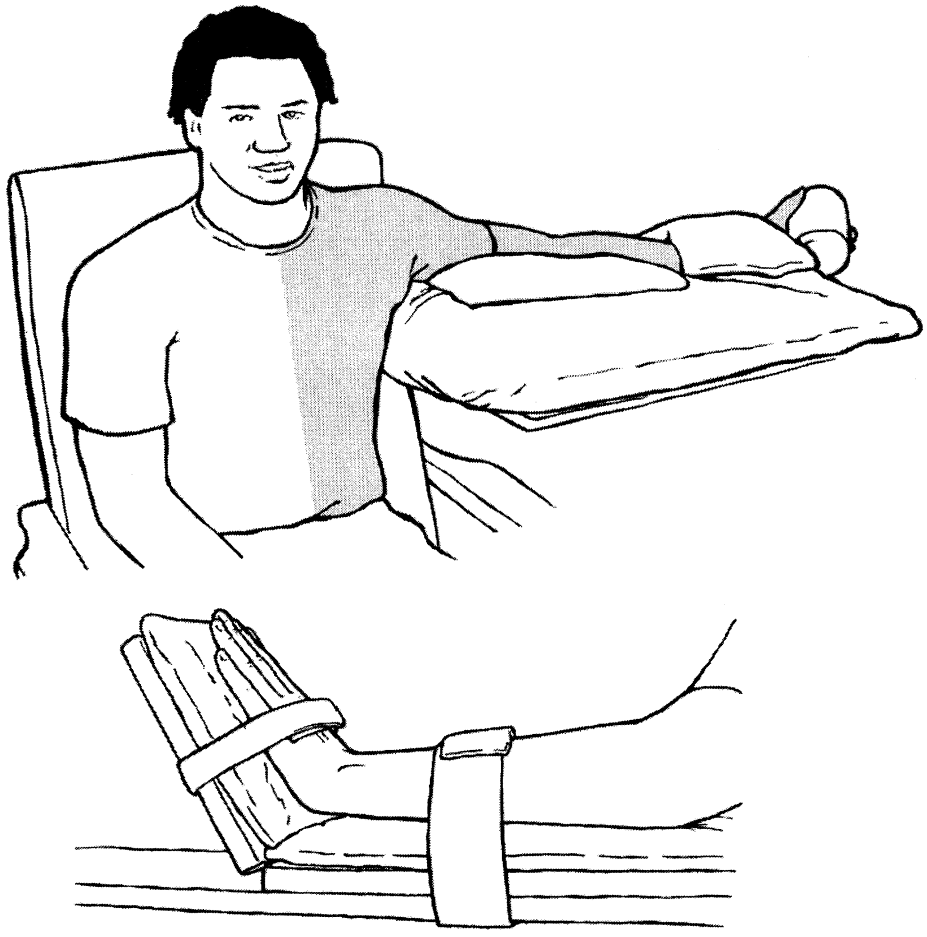

Figure 2 Shoulder position to extend shoulder adductors, internal rotators and elbow flexors and wrist position to stretch wrist and finger flexor muscles. Both positions could also be carried out in lying.

record sheet kept on a clipboard at the end of the subject's bed. Positioning was to continue throughout the hospital admission or until the subject recovered arm function, determined by the ability to pick up a polystyrene cup, or until 12 weeks post stroke, whichever was the sooner.

Control group subjects received only standard care. On visits to the ward no incidents of control group subjects receiving the stretch positions were observed and none were reported by ward staff or patients. Since subjects were dependent on the provision of equipment and assistance to position their arms, sustained self-stretching in the control subjects was unlikely.

Measurement procedures

Outcomes were passive range of wrist extension with fingers extended and passive range of shoulder external rotation either to a standard force or to pain. Voluntary wrist extension range with fingers extended and voluntary external rotation of the shoulder were also measured. One of the investigators (AT) and an assistant carried out the measurement procedures. All goniometer readings were taken by the assistant who was (when possible) kept blind to the subject's allocation.

Range of motion was measured immediately after three passive movements had been

administered. This served to reduce before measurement any short-term visco-elastic changes that occur as a result of movement.[20] Wrist extension was assessed using a standard torque controlled procedure.[21] The subject's hand with fingers extended was strapped to an aluminium plate (222 × 133 × 1 mm). The subject's forearm rested on a table with the elbow at 90 degrees and with the hand plate overlapping the edge, so that the wrist was in neutral position to start with. Using a spring balance hooked into the end of the plate, the wrist was pulled slowly into extension with the spring balance held perpendicular to the plate. The force applied was 0.5 kg or to pain, whichever occurred sooner. The resulting angle of wrist extension was measured using a fluid-filled goniometer, which was hand held gently (not pressed) on the underside of the plate (see Figure 3a). The 0.5-kg force used was tested on a group of 22 normal subjects who were over 60 years old. With a lever arm of 225 mm, the 0.5-kg force was sufficient to extend the wrist beyond the voluntary active range in all but one of them. Only one of the normal subjects reported pain from the procedure. Active range of wrist extension was measured with the hand still on the plate.

To assess passive range of external rotation at the shoulder the subject sat next to a table of adjustable height. A gutter attached to a swinging arm was clamped to the edge of the table over the top of a large protractor scale. The subject's forearm was positioned in the gutter and the hand was strapped to a plate that slid along the swinging arm to fit the subject's forearm and hand length. The height of the table was adjusted so that the subject's elbow was flexed at 90 degrees with the upper arm close to the trunk. The criterion for this was that the subject's shoulder should rest in less than 20 degrees of abduction. With one hand on the subject's forearm to ensure it did not lift from the gutter and the other hand on the spring balance attached to the distal end of the apparatus, AT slowly applied torque perpendicular to the swinging arm until the spring balance registered 1 kg or the subject reported pain or winced. The resulting degree of rotation was read from the protractor scale (Figure 3b). Again the 1-kg force applied was sufficient to exceed the active voluntary range in all but one of 20 normal subjects tested and none reported discomfort from the procedure. Voluntary range of external rotation of the shoulder was also measured with arm and hand still in the swinging arm apparatus.

Three range of movement measurements were taken on each occasion and average performance was used in analysis. In addition to the affected side measurements the unaffected side was tested on at least two occasions for comparison.

Data analysis

Frequency of positioning for the experimental group was plotted as a function of weeks after stroke when the subject received at least seven wrist or shoulder stretches a week and also as the total number of stretches achieved per week.

Range of motion measurements were expressed in degrees. The amount of 'contracture' or loss of joint range on the affected side was calculated by finding the difference between the mean range on the affected and unaffected sides. The data from two patients (C12, E13) who did not complete all three measurement sessions was discarded. Using SPSS software the data were tested for sphericity (Mauchley's test) before repeated measures analysis of variance was performed (factor 1: weeks post stroke, factor 2: group). When sphericity was significant the Greenhouse–Geiger adjustment was applied. Differences in range of motion and contracture between the assessment weeks were calculated for each subject. These differences between groups were tested with independent samples t-tests to determine confidence intervals of the effects of stretching. Paired t-tests of range of motion and contracture scores were performed to test for differences in loss of range between the three assessment times. The significance level for all tests was set to 95%, $p > 0.05$.

Results

Compliance to the stretch regime

Thirteen subjects were allocated to arm stretch positioning. Ten received the stretches on the ward. Three subjects (10, 11 and 12) who spent most of the day in the physiotherapy gym had all stretch positions carried out by physiotherapy staff. Adherence to the stretch regime carried out on the ward was very variable (see subjects' 1–9 and 13, Figure 4). Frequency of positioning was fair from

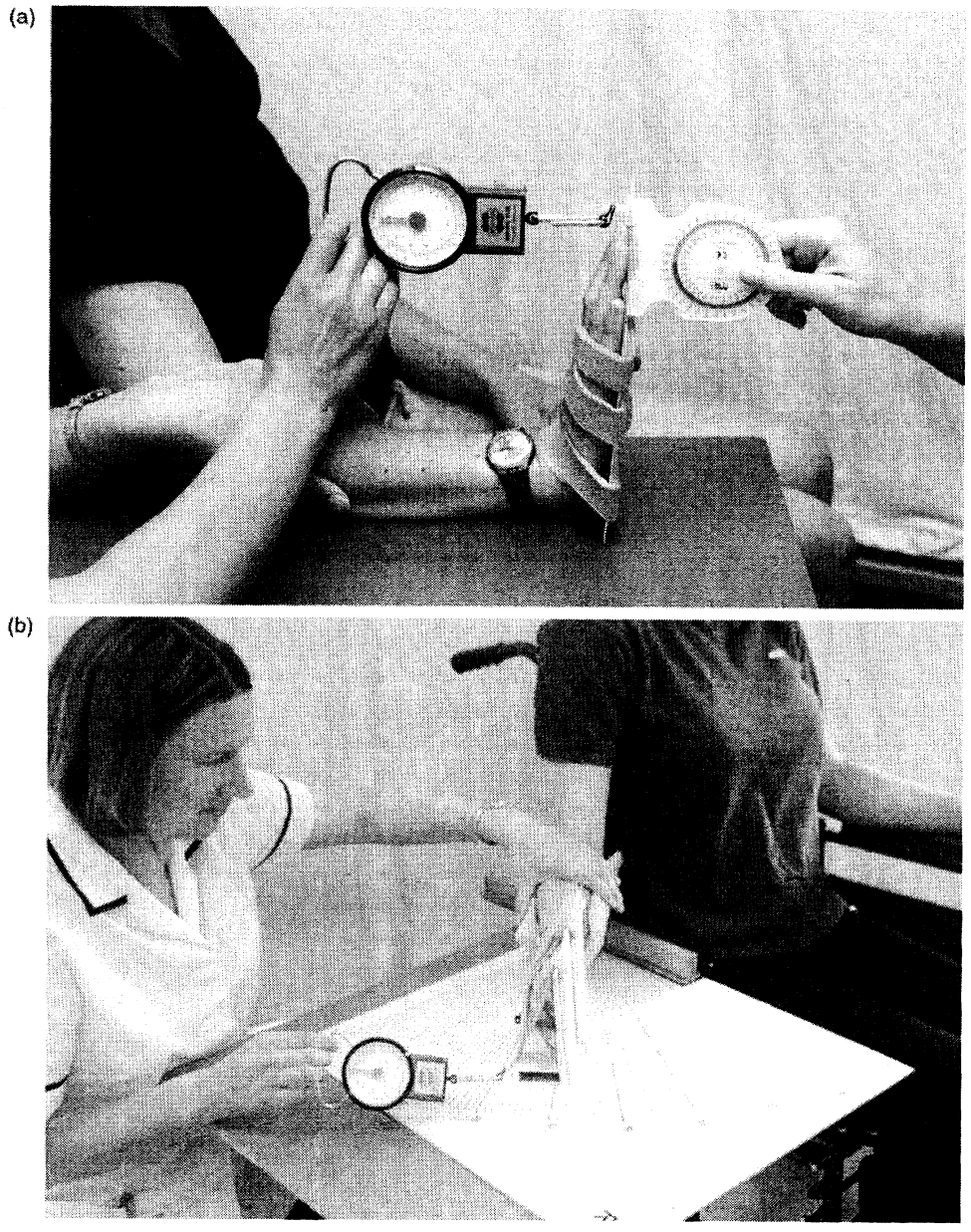

Figure 3 Set up for measurement: (a) wrist extension and (b) shoulder external rotation to standard force.

four to eight weeks post stroke but declined after that. Mean (SD) frequency of stretch positions completed between four and eight weeks for the whole group was 36.5 (13.0) for wrist, 31.2 (14.1) for shoulder, out of 56 prescribed. Eight subjects achieved at least seven wrist stretches a week for three weeks between four and eight weeks post stroke and eight achieved at least seven shoulder stretches a week over that time.

Reasons for the shortfall in the number of stretch positions completed per week were that: the subject declined or was unavailable, staff

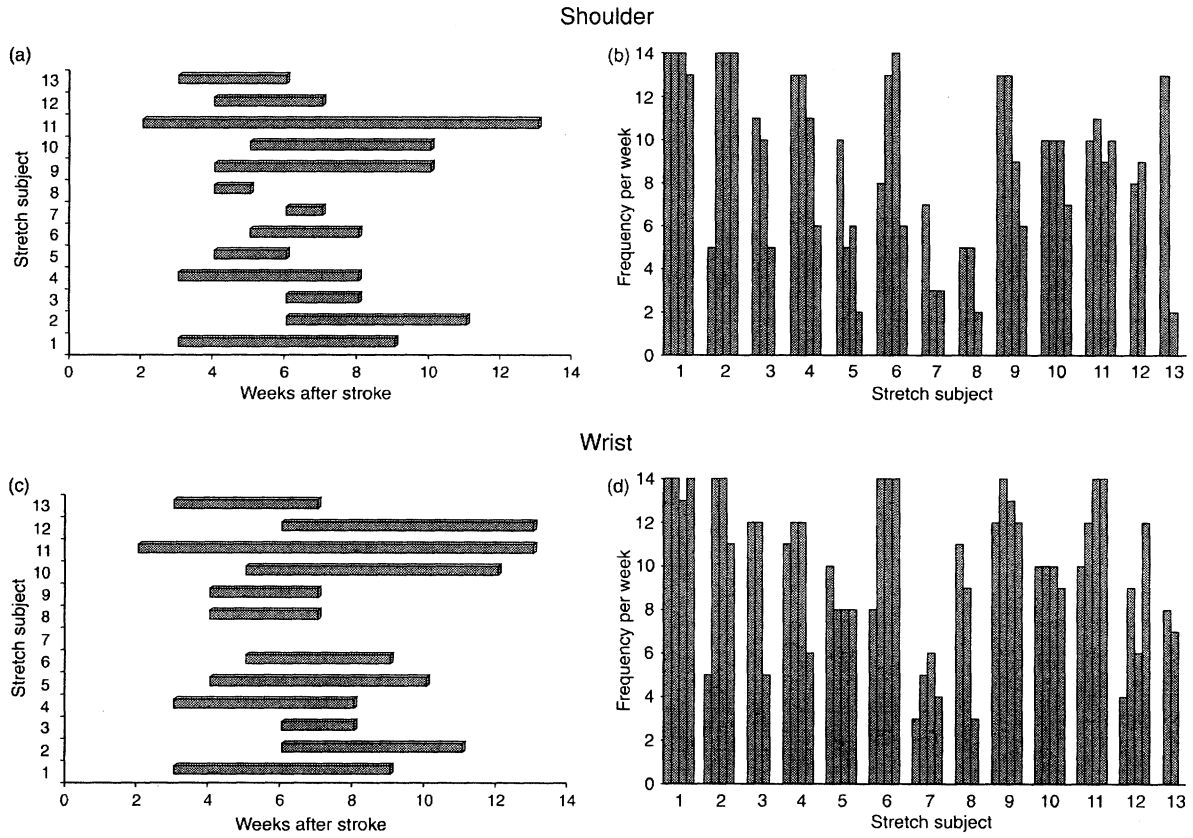

Figure 4 Compliance to shoulder and wrist positions. (a) and (c) show the weeks after stroke when subjects received at least one 30-min stretch a day. (b) and (d) show the number of stretches per week during weeks 5, 6, 7 and 8 after stroke. The four columns refer to four weeks per subject.

noncompliance or, in the case of subject nine, to illness. Only six subjects continued the treatment until discharge or 12 weeks post stroke. Three subjects developed shoulder pain and stopped the treatment, two decided to stop due to discomfort in the hand or wrist. It is not possible to determine whether the positioning regime contributed to or caused the onset of pain, since shoulder and hand pain are common secondary complications of stroke[22,23] especially in those with little or no arm movement, such as this study sample. One subject who was restless and inattentive to the affected side stopped the stretch treatment early because she was unable to maintain the positions. At least four subjects disliked having to stay on the ward for the treatment, especially on warm sunny days.

Effects of treatment

Mean (SD) of passive range of motion and contracture scores, together with mean (SD) differences within groups, and mean (95% CI) differences between groups are listed in Tables 2 and 3. No significant differences in loss of range at the shoulder or the wrist were found between the experimental and control groups at any of the assessment times. All differences between sessions are numerically small and inconsistent in their direction.

Given that compliance to treatment was low in some individuals, it is useful to consider the results of subjects with good compliance. For this reason data points representing range of motion of two subjects with excellent compliance (subjects 1 and 11) are marked in Figure 5. Both of these subjects

Table 2 Mean (SD) passive range of motion and contractures at each measurement session

Outcome	Scores					
	Week 4		Week 8		Week 12	
	Con ($n=11$)	Exp ($n=12$)	Con ($n=11$)	Exp ($n=12$)	Con ($n=11$)	Exp ($n=12$)
Affected shoulder external rotation (degrees)	49.7 (11.1)	53 (11.9)	40.5 (17)	48.3 (13.6)	34.8 (22.8)	37 (18.1)
Affected shoulder external rotation contracture (i.e., unaffected minus affected) (degrees)	27.5 (11.8)	21.3 (16.5)	34.7 (20)	30.5 (17.3)	42.5 (25.8)	42.5 (16)
Affected wrist extension (degrees)	55.4 (8)	60 (12.5)	46.1 (18.2)	48.6 (11.9)	45.5 (18.9)	44.5 (13.8)
Affected wrist extension contracture (i.e., unaffected minus affected) (degrees)	22.6 (7.6)	19.1 (14.3)	31.4 (17)	31.5 (15.4)	34.7 (16.9)	34.7 (17.2)

Con, control group; exp, experimental group.

started the stretch treatment early at two and three weeks post stroke respectively (see Figure 4), but despite this both lost considerable wrist extension in the first eight weeks. At four weeks subject 1's shoulder external rotation on the affected side was 46 degrees (i.e., 24 degrees less than the range of the unaffected side). He maintained his 46 degrees at the eight-week assessment when he stopped the stretch treatment due to pain. At 12 weeks his range was little different at 42 degrees. Subject 11 lost considerable shoulder range over the course of the study despite persisting with the programme until 12 weeks post stroke.

Loss of range of motion within groups

The effects of time post stroke on range of movement were statistically significant (shoulder $F=14.1(1.45,30.54)$, $p<0.001$, wrist $F=10.9$ $(2,42)$, $p<0.001$). These differences were still reliable when the data were expressed as contracture (shoulder $F=16.2(2,42)$, $p<0.001$, wrist $F=12.5$ $(2,42)$, $p<0.001$). Since there was no significant difference between groups, results from subjects in both groups were analysed together. At four weeks post stroke the mean passive range of the affected side shoulder was 51 degrees. By eight weeks this was reduced to 45 degrees and at 12 weeks it was 36 degrees. When subtracted from the range on the unaffected side these measurements represent mean contractures of 24, 33 and 43 degrees respectively. At four weeks the mean wrist range was 58 degrees, eight weeks: 47 degrees, twelve weeks: 45 degrees. At four weeks the mean contractures were 21 degrees, eight weeks 31 degrees, twelve weeks 35 degrees. Increases in contracture between four and eight weeks were statistically significant (shoulder $t=3.2$, $p<0.01$; wrist $t=3.5$, $p<0.01$). Between eight and twelve weeks loss of range at the shoulder was significant ($t=3.1$, $p<0.01$), but loss of range at the wrist was not.

There was considerable variability in the amount of range lost. In part this is probably explained by the degree of recovery in the first few weeks. Subjects represented in the upper quartile ranges at eight and twelve weeks typically had recovered some active movement.

Discussion

In evaluating the effectiveness of a new treatment it is not only important to determine the efficacy of the intervention but it is important to establish its acceptability to patients and to clinical staff. Daily adherence to the stretch positioning regime in this study varied between subjects and was not well tolerated over more than three weeks. Other studies have reported no difficulties in delivering between 30 and 60 minutes of stretching for a periods of four and six weeks.[16,24,25] The positioning in these studies has been carried out by physiotherapists. Physiotherapists, who have a particular interest in muscle length changes, may well deliver the stretch positioning treatment with more commitment, enthusiasm and authority than

Table 3 Mean (SD) of differences in passive range of motion and contractures between measurement sessions within groups and effect sizes plus 95% confidence intervals (CI) between groups

Outcome	Mean (SD) differences within groups						Mean (95% CI) differences between groups		
	Wk 8 – wk 4		Wk 12 – wk 8		Wk 12 – wk 4		Wk 8 – wk 4	Wk 12 – wk 8	Wk 12 – wk 4
	Con ($n = 1$)	Exp ($n = 12$)	Con ($n = 11$)	Exp ($n = 12$)	Con ($n = 11$)	Exp ($n = 12$)	Exp–con	Exp–con	Exp–con
Affected shoulder external rotation (degrees)	−9.3 (11.2)	−4.8 (9.9)	−5.6 (14.2)	−11.3 (11.4)	−14.9 (18.4)	−16 (16.8)	4.5 (CI −13.7 to 4.6)	−5.6 (CI −5.5 to 16.7)	−1.1 (CI −14.2 to 16.4)
Affected shoulder external rotation contracture (i.e., unaffected minus affected) (degrees)	7.3 (14.4)	9.3 (10.3)	7.8 (17.8)	12 (12.9)	15.1 (19.5)	21.3 (15.6)	2 (CI −12.8 to 8.8)	4.2 (CI −17.6 to 9.2)	6.2 (CI −21.4 to 9.1)
Affected wrist extension (degrees)	−9.3 (13.5)	−11.4 (12.4)	−0.6 (13.7)	−4.1 (9.07)	−9.9 (13.9)	−15 (19.6)	−2.1 (CI −9.1 to 13.36)	−3.4 (CI −6.6 to 13.5)	−5.6 (CI −8.8 to 20.0)
Affected wrist extension contracture (i.e., unaffected minus affected) (degrees)	8.7 (16.3)	12.4 (13.1)	3.4 (14.2)	3.2 (8.1)	12.1 (14)	15.6 (16.1)	3.7 (CI −16.5 to 9.1)	−0.2 (CI −9.7 to 10.1)	3.5 (CI −16.7 to 9.7)

Con, control group; exp, experimental group.

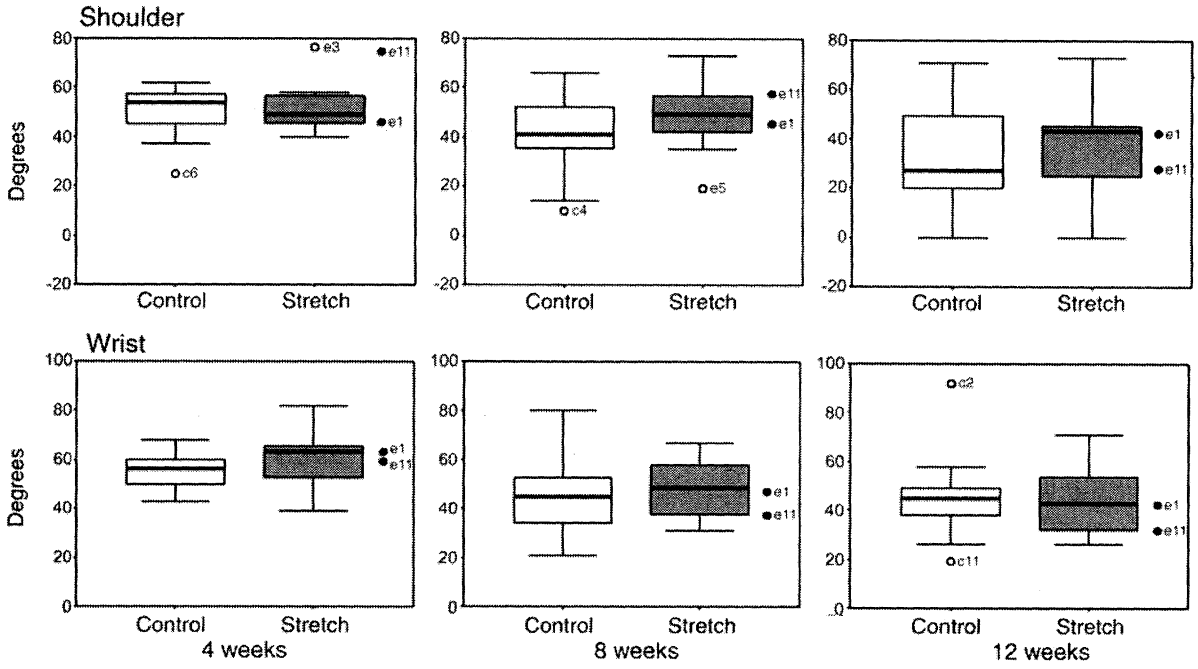

Figure 5 Passive range of movement in degrees for control ($n = 11$) and intervention group ($n = 12$) at four, eight and twelve weeks after stroke. Box plots represent the interquartile ranges that contain 50% of values. The whiskers extend from the box to the highest and lowest values, excluding outliers. The line across the box indicates the median. Outliers are represented by open circles and labelled with the subject number. Data points for subjects 1 and 11 (both subjects with excellent compliance) are indicated with black circles.

other members of the clinical team. Such enthusiasm would probably influence patients' attitudes to the treatment too. The environment may also make a difference. The three subjects who were positioned in the physiotherapy gym all had excellent compliance. However this option would not be available to subjects who do not have the stamina or the desire to stay in the physiotherapy gym for long periods of the day. Perhaps choosing just one position to be sustained for a shorter duration would result in better compliance on the wards. A less demanding regime would also be more manageable since then only one or two staff members would need to take responsibility for carrying it out.

Although there were problems with compliance to our demanding regime three-quarters of the intervention group did have at least seven 30-min stretches a week for both shoulder and wrist for at least three weeks. Given this amount of treatment delivered comparison between the intervention and control groups yielded no statistical difference in passive range of movement to standard force. The variability in range of motion and the small sample size resulted in low statistical power. Another stroke study had a similar nonsignificant result[16] and studies looking at the effects of four weeks of daily 30-min stretches on the lower limb muscle extensibility of spinal cord injured subjects have also found no significant effects.[24,25]

The stretch positioning regime tested involved a considerable investment in time. In a discussion with stroke service physiotherapists there was consensus that a large saving in range is needed to justify the time and tolerance required of both patients and staff in carrying out this treatment regime. Based on the data collected in this study, in order to have 90% power to detect a 1 SD difference in the range of wrist extension and external rotation of the shoulder, a minimum of 23 subjects per group would be needed to determine the effectiveness of treatment at eight and twelve weeks after stroke.

Clinical messages

- Considerable range of motion is lost in the early weeks after stroke in patients without arm function. Any preventative treatment should start as soon as possible after onset.
- Demanding stretch positioning regimes are poorly tolerated over many weeks following stroke.

A larger study might find a significant effect of stretching but there are feasibility issues in carrying this out. Despite loss of arm function being common after stroke we had difficulty in recruiting patients to the study early after stroke. Since we were interested in determining whether the stretch treatment was effective for preventing contractures we wanted initially to recruit patients within two weeks of stroke. This proved to be difficult because many patients were considered to be too unwell to tolerate the stretch regime or even to approach for consent at this acute stage. We increased our entry criteria to four weeks after stroke but still failed to recruit sufficient patients.

Using standardized forces to measure range of movement the study has provided a quantitative picture of the loss of range over time and has shown that in subjects without hand function considerable range is lost in the first four weeks after stroke. This early loss of range post stroke is in agreement with a recent pilot study of the time course of development of contractures at the wrist.[26] Loss of range between four and eight weeks was markedly less. This could be due to increased participation in therapy and recovery of muscle activation in some patients after the acute phase or it may be that length tension changes in muscle and soft tissues naturally follow an exponential time course.

A difference was seen in the time course of loss of range of motion between the wrist and shoulder. The mean shoulder external rotation range continued to deteriorate after eight weeks while the range of wrist extension tended to plateau. It may be that patients passively mobilize the wrist and fingers in a bid to get them working and to ease the stiffness they see developing. It is not easy to keep the shoulder mobile by self-ranging.

All subjects in this study lost considerable range of motion and it is important that an acceptable and effective treatment to prevent contractures is found and that any such treatment is implemented very early after stroke.

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