

Prevention of Shoulder Subluxation After Stroke With Electrical Stimulation

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Background and Purpose—Subluxation is a significant problem in poststroke hemiplegia, resulting in pain and loss of function. Current treatments are not proved and not considered effective. It has been demonstrated that cyclical electrical stimulation of the shoulder muscles can reduce existing subluxation. The purpose of this study was to determine whether electrical stimulation could prevent subluxation in both the short and long terms.

Methods—A prospective, randomized controlled study was used to determine the efficacy of electrical stimulation in preventing shoulder subluxation in patients after cerebrovascular accidents. Forty patients were selected and randomly assigned to a control or treatment group. They had their first assessment within 48 hours of their stroke, and those in the treatment group were immediately put on a regimen of electrical stimulation for 4 weeks. All patients were assessed at 4 weeks after stroke and then again at 12 weeks after stroke. Assessments were made of shoulder subluxation, pain, and motor control.

Results—The treatment group had significantly less subluxation and pain after the treatment period, but at the end of the follow-up period there were no significant differences between the 2 groups.

Conclusions—Electrical stimulation can prevent shoulder subluxation, but this effect was not maintained after the withdrawal of treatment. (*Stroke*. 1999;30:963-968.)

Key Words: electric stimulation ■ randomized controlled trials ■ rehabilitation ■ shoulder ■ stroke

Subluxation of the glenohumeral joint is a well-recognized complication experienced by stroke patients. The reported incidence of shoulder subluxation varies greatly, from 17%¹ to 81%.² The vulnerability of the glenohumeral joint to subluxation is a function of the anatomy of the joint. As an extremely mobile joint, it sacrifices stability for mobility.³ Basmajian⁴ determined through electromyographic studies that the supraspinatus, and to a lesser extent the posterior deltoid muscles, played a key role in maintaining glenohumeral alignment. Chaco and Wolf⁵ also demonstrated the importance of the supraspinatus muscle in preventing downward subluxation of the humerus.

Traditionally, slings have been applied to prevent or reduce shoulder subluxation after stroke. The most effective slings have the drawback of holding the limb in a poor position that is likely to cause soft tissue contracture and have a disadvantageous effect on symmetry, balance, and body image.⁶⁻⁹

In view of the shortcomings associated with the use of slings, alternative approaches to deal with this problem have been sought. Two studies^{10,11} have investigated the application of electrical stimulation to the supraspinatus and posterior deltoid muscles.

Faghri et al¹¹ recruited 26 patients on average 17 days after stroke and allocated them randomly to experimental and control groups. Subjects in the experimental group demonstrated a mean

subluxation of 6 mm on initial x-ray, and the control group showed a mean subluxation of 4 mm. The experimental group received a program of electrical stimulation for 6 weeks, followed by a nontreatment period of 6 weeks. Baker and Parker¹⁰ used a similar method in their study of 63 subjects, with the main difference being that all subjects had a chronic subluxation of at least 5 mm compared with the unaffected arm. Both studies demonstrated a beneficial effect on subluxation over the treatment period, with that Faghri et al¹¹ showing improvement in other parameters, such as pain, range of motion, and arm function. However, both studies showed deterioration following withdrawal of electrical stimulation, although not back to pretreatment levels.

These studies recruited subjects with preexisting shoulder subluxation, and the treatment did not resolve this problem. Patient outcome may be enhanced if shoulder subluxation can be prevented, thus potentially avoiding the associated complications.

The purpose of this study was to evaluate the effectiveness of using electrical stimulation immediately after stroke to prevent glenohumeral subluxation and prevent possible associated problems of shoulder pain and impaired motor function.

Subjects and Methods

The study design was a prospective, single-blind, randomized controlled trial. Subjects were recruited from the Acute Stroke Unit,

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TABLE 1. Summary Details of the Treatment and Control Groups

Group	Mean Age, n	Gender, n		Affected Side, n		Classification, n			
		Male	Female	Right	Left	PACI	LACI	POCI	HEM
Treatment	71	8	12	4	16	7	11	1	1
Control	73	10	10	5	15	8	10	0	2

Mean age of each group is given. Subjects were classified using the Oxford classification.¹² PACI indicates partial anterior circulation infarct; TACI, total anterior circulation infarct; LACI, lacunar infarct; POCI, posterior circulation infarct; and HEM, hemorrhage.

Western Infirmary, Glasgow, Scotland. The recruitment criteria were the following: (1) no previous pathology to the shoulder; (2) the patient's cerebrovascular accident must have resulted in significant motor deficit of the upper limb with a grade of ≤ 2 on the Manual Muscle Test¹²; (3) adequate communication ability to cope with a verbal rating score for pain; (4) no cardiac pacemaker or metal in situ; (5) no women of childbearing age (because of x-rays); and (6) recruitment and all initial measurements must have been completed and treatment commenced within 48 hours of admission to the Acute Stroke Unit. Forty subjects were recruited and randomized into treatment and control groups before initial assessments.

A total of 40 subjects were recruited, and all completed the study (Table 1). Eighteen men and 22 women were recruited; 9 had a right-sided hemiparesis and 31 a left-sided hemiparesis. This imbalance was a result of the recruitment criterion requiring sufficient communication ability to cope with a verbal rating score for pain, which excluded many subjects with right-sided hemiparesis. The age range was from 45 to 84 years. The mean age for the treatment group was 71 years and that for the control group 73 years. Two subjects were unable to complete all measurements because they were unable to travel to the radiography department for final x-rays; all the other measures, however, were completed on these subjects. The classification of strokes, made according to the Oxford classification system,¹² is shown in Table 1.

The overall study design is given in Table 2. All assessments were made, before any therapy was given, by an assessor blinded to the protocol. Initial assessments were carried out within 48 hours of admission. Subjects in the treatment group received a program of electrical stimulation over the next 4 weeks (treatment period) in addition to conventional physiotherapy and occupational therapy. Subjects in the control group received their conventional physiotherapy and occupational therapy only during this period (treatment period). A second set of measurements were made at the end of this 4-week period. Both treatment and control groups continued with conventional physiotherapy and occupational therapy for the next 8 weeks (follow-up period). Final measurements were made 3 months after stroke. Over the follow-up period, no electrical stimulation was applied. The period from first to final assessment is referred to as the "total study period."

Subjects received electrical stimulation 4 times each day, with a minimum of 2 hours between sessions. The length of each session was increased gradually, starting at 30 minutes in week 1, 45 minutes in weeks 2 and 3, and 60 minutes in week 4. Two electrodes were positioned on the supraspinous fossa and the posterior aspect of the

upper arm to stimulate the supraspinatus and posterior deltoid muscles. This position was checked in a pilot study before beginning the project to ensure that the movement obtained produced good correction of subluxation (Figure 1). The stimulation consisted of asymmetrical biphasic pulses with a pulse width of 300 μ s applied at a frequency of 30 Hz. The duty cycle was 15 seconds on, which incorporated a ramp up time of 3 seconds and a ramp down time of 3 seconds and 15 seconds off.

Outcome Measures

Measurements were made of shoulder subluxation (radiological), pain, arm girth and motor control.

Shoulder subluxation was assessed by a single AP radiograph taken of the affected shoulder. Two methods were used for evaluating the X-rays. One method was a categorization of subluxation 1 to 4¹⁴ (Figure 2). In the second method, the displacement was quantified. This involved using a line bisecting the glenoid fossa, then measuring the distance from the line to the most superior aspect of the head of the humerus (Figure 3).

Pain was assessed by measuring the pain-free range of passive lateral rotation (PLRL) using a clinical goniometer, where a loss of range indicated an increase in pain.¹⁵ Subjects were also asked to grade the pain they perceived on a verbal rating scale (0=none, 1=slight, 2=moderate, 3=severe, and 4=very severe).¹⁴

Motor function was assessed by the upper arm section of the Motor Assessment Scale.¹⁶ This tests the subjects' ability to perform motor tasks of increasing difficulty on a scale of 0 to 6 (0=poor function, 6=good function).

Measurement of upper arm girth was made to monitor changes in muscle bulk. This was measured with a tape measure wrapped around the upper arm from the axillary fold. The distance from the acromial process to the tape was recorded to aid accuracy of repeat measurement.

The main hypotheses of this study were that (1) electrical stimulation applied immediately after stroke could prevent the development of shoulder subluxation and (2) a program of electrical stimulation would have a beneficial effect in preventing pain, motor impairment, and muscle atrophy.

To test these hypotheses, the change for all outcome measures over both the treatment period and the control period for each subject was calculated. The Mann-Whitney *U* test was used to test for significant differences of these changes between the control and treatment groups over the treatment period, the follow-up period, and the total study period.

TABLE 2. Study Design

Group	Assessment 1	Treatment Period	Assessment 2	Follow-Up Period	Assessment 3
Treatment	X-ray	ES	X-ray	PT+OT	X-ray
	Pain, clinical	PT+OT	Pain, clinical		Pain, clinical
Control	X-ray	PT+OT	X-ray	PT+OT	X-ray
	Pain, clinical		Pain, clinical		Pain, clinical

Both groups were assessed at the start of the study, immediately after the treatment period and, immediately after the follow-up period. The treatment period was of 4 weeks duration and the follow-up period was 8 weeks. ES indicates electrical stimulation; PT, physiotherapy; and OT, occupational therapy.

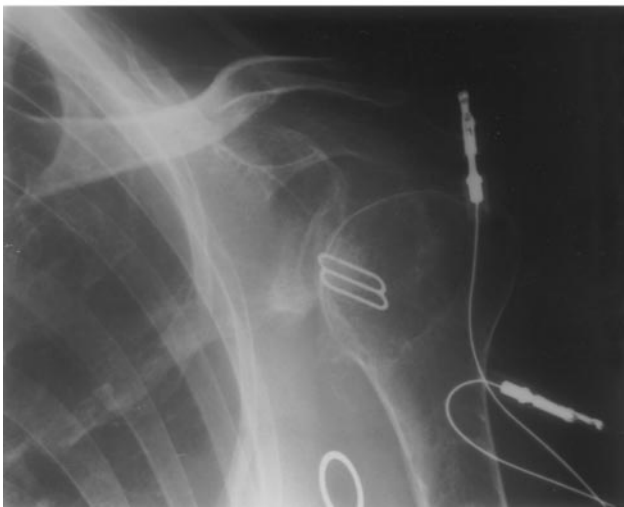


Figure 1. Use of electrical stimulation to correct shoulder subluxation. The top image is that of a person with chronic shoulder subluxation. The bottom image shows the position of this shoulder during application of electrical stimulation.

Results

This study shows that the control group had greater subluxation over the treatment period than the treatment group. This difference was not maintained over the total study period after withdrawal of treatment. None of the patients in the control group or the treatment group used a sling during this study.

The control group demonstrated greater subluxation than the treatment group over the treatment period, with a mean subluxation grade score of 0.80 compared with 0.30 in the treatment group ($P=0.067$; Mann-Whitney U test) (Figure 4). The results of the humeral displacement measure followed the same pattern as the subluxation grading, with a mean change of 0.63 cm in the control group compared with 0.22 cm in the treatment group ($P=0.06$; Mann-Whitney U test)

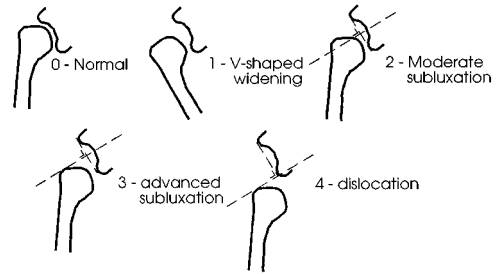


Figure 2. Subluxation gradings. The method used was that described by Van Langenberghe and Hogan.¹⁴ The 2 dashed lines shown are the line connected the most superior and inferior margins of the glenoid fossa and the line bisecting it.

At the end of the follow-up period, subluxation grade score for both groups was the same (0.63). The change in subluxation grading in the treatment group over the follow-up period was significantly greater than that in the control group ($P=0.019$; Mann-Whitney U test). The mean change in the vertical displacement measure over the follow-up period for the control group was -0.05 cm (indicating improvement) in the control group and 0.3 cm (indicating further subluxation) in the treatment group ($P=0.22$; Mann-Whitney U test).

Over the total study period, there was no significant difference between the groups in either the subluxation grading or the humeral displacement measure, with the mean subluxation grade for both groups 0.63 at final assessment ($P=0.955$; Mann-Whitney U test). The mean change in the vertical displacement measure over the total study period was 0.62 cm in the control group and 0.52 cm in the treatment group ($P=0.748$; Mann-Whitney U test).

There was no difference in the changes in the motor scores between the groups over any intervention period (Figure 5).

Both the treatment and control groups demonstrated a loss of passive range of lateral rotation over the first intervention period, but a greater reduction was seen in the control group ($P=0.172$).

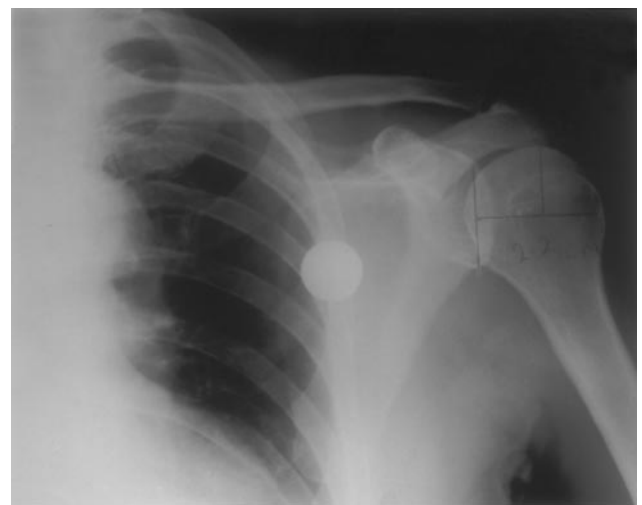


Figure 3. Measurement of shoulder subluxation. The 2 dashed lines shown are the line connecting the most superior and inferior margins of the glenoid fossa and the line bisecting it. The distance from the second line to the superior point of the head of the humerus was measured. The circular object over the scapula was a ball bearing placed to ensure consistency of x-ray enlargement.

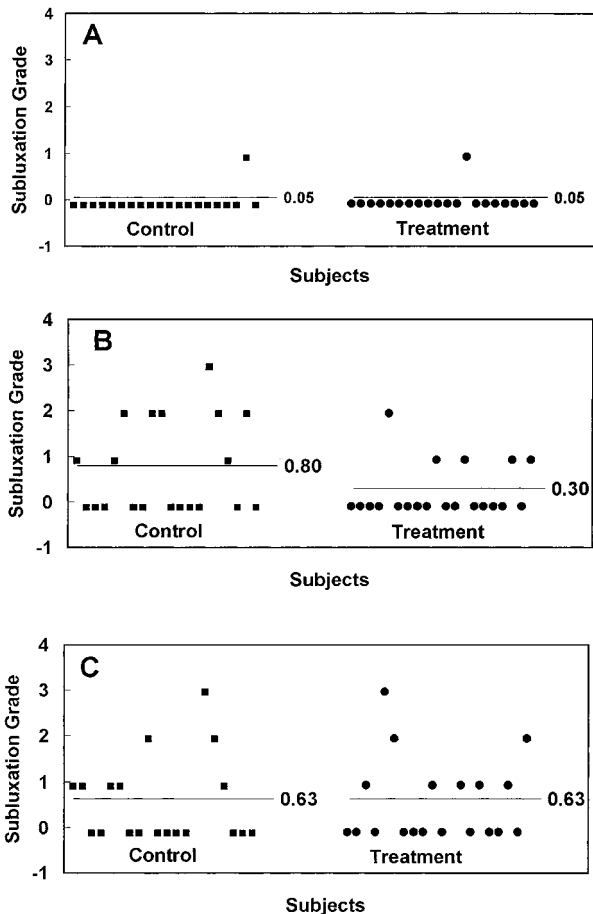


Figure 4. Subluxation grades. The subluxation grades for each subject in both the control and the treatment groups are shown for the first assessment (A), the second assessment (B), and the final assessment (C). The mean values for the control and the treatment groups are indicated by the solid lines.

The overall change over the total study period showed no difference between the groups ($P=0.881$; Figure 6).

Both groups demonstrated an increase in pain as measured by the verbal rating scale (Table 3). No significant difference was found between the groups over any period in this pain measure.

Both groups demonstrated a loss of arm girth over the treatment period (Table 4), with a trend toward greater loss seen in the control group ($P=0.071$). Further loss of girth was shown over the follow-up period, but there was no significant difference between the groups. The change in the upper arm girth over the study period showed no significant difference between the groups.

A correlation was found between the change in subluxation grading and the actual motor score at the end of the treatment and follow-up periods for the total study group (Spearman correlation coefficients of 0.67 [$P=0.00$] and 0.69 [$P=0.00$], respectively), the control group (correlation coefficients of 0.76 [$P=0.00$] and 0.67 [$P=0.00$], respectively), and the treatment group (correlation coefficients of 0.27 [$P=0.25$] and 0.74 [$P=0.00$], respectively).

Discussion

The work of Chaco and Wolf⁵ clearly demonstrated that subluxation is most likely to occur in the first 3 weeks after

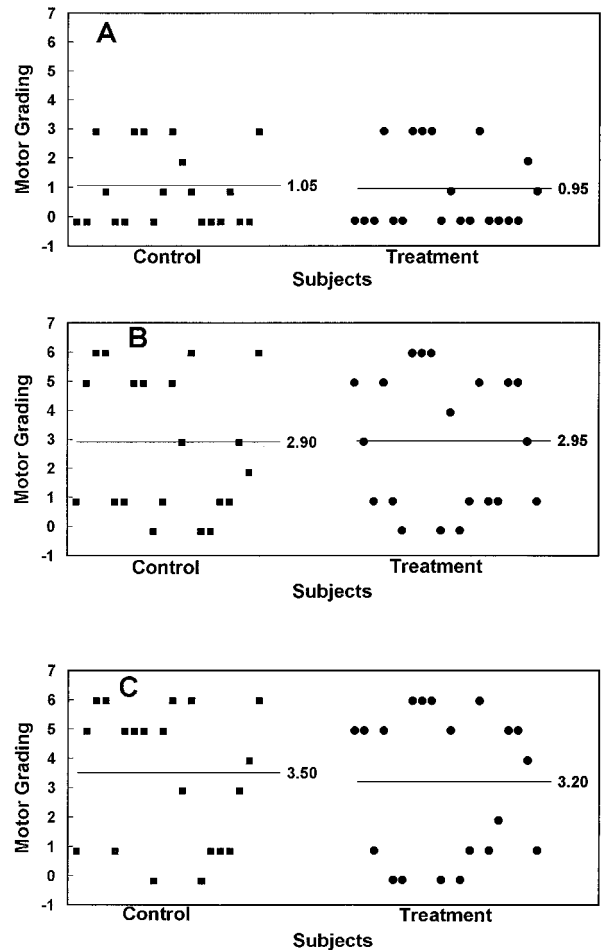


Figure 5. Motor grading. The motor grades for each subject in both the control and the treatment groups are shown for the first assessment (A), the second assessment (B), and the final assessment (C). The mean values for the control and the treatment groups are indicated by the solid lines.

stroke, while the limb is still flaccid and, in particular, the supraspinatus muscle inactive. In the present study, significantly greater subluxation occurred in the control group than in the treatment group over the treatment period. This suggests that the application of electrical stimulation prevented subluxation. Over the follow-up period this pattern was reversed, with the treatment group now deteriorating and the control group showing an improvement in the subluxation measures.

The explanation for this could be that in the control group, all the subjects who subluxed did so in the initial period, and as motor status improved (Figure 4) some improvement in alignment was observed over the follow-up period. In the treatment group, however, subluxation that would have occurred over the initial treatment period was prevented by electrical stimulation, but this potential to sublux was realized after withdrawal of treatment.

The relationship between motor recovery, subluxation, and the effect of electrical stimulation is reinforced by correlation of motor scores and subluxation measures. When the groups were analyzed separately, a strong correlation was found between the motor scores (at the end of the treatment period)

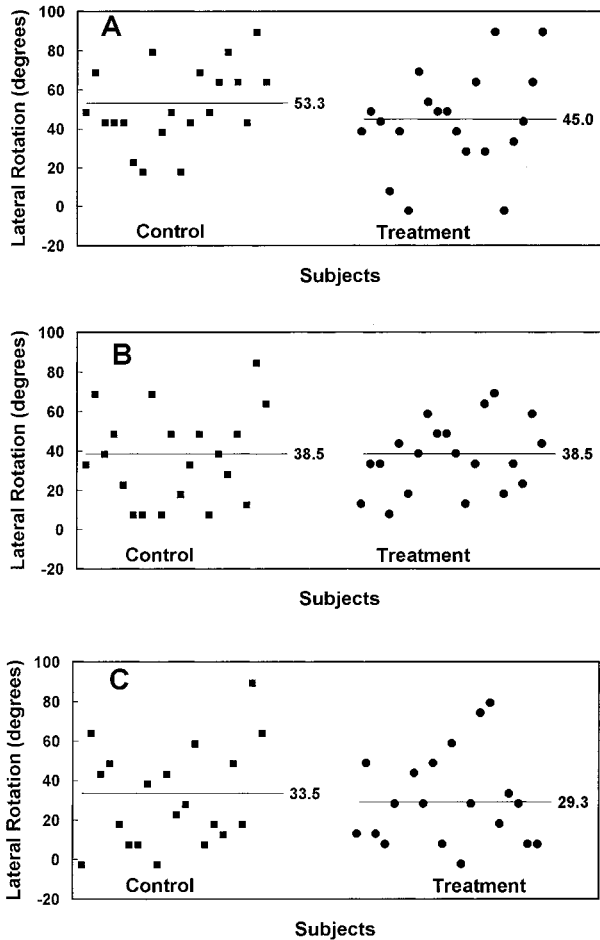


Figure 6. Pain-free range of lateral rotation. The range for each subject in both the control and the treatment groups are shown for the first assessment (A), the second assessment (B), and the final assessment (C). The mean values for the control and the treatment groups are indicated by the solid lines.

and the subluxation grading over the initial treatment period. This was not seen in the treatment group over this period, which supports the proposition that the electrical stimulation was having an effect.

Over the follow-up period the correlation became weaker in the control group but much stronger in the treatment group. The stimulation protocol in the current study differed from previous work, and treatment was applied for a shorter time (4 weeks compared with 6 weeks). More importantly, the current study recruited subjects much sooner than the previous work, ie, prior to the development of subluxation. Faghri

TABLE 4. Upper Arm Girth

Assessment	Arm Girth, cm			
	Control Group		Treatment Group	
	Mean	SD	Mean	SD
1	30.63	4.09	31.36	3.19
2	29.39	3.61	30.77	3.39
3	29.19	3.55	30.75	3.21

Mean and SD of upper arm girth for each assessment is shown.

et al¹¹ demonstrated that shoulder subluxation could be reduced by the use of electrical stimulation. However, this study showed that it is possible to prevent or limit shoulder subluxation immediately after a stroke.

No difference was seen between the groups in motor recovery. It was not anticipated that the application of electrical stimulation would directly improve motor recovery, except as a secondary consequence of preventing subluxation and pain. The fact that no difference was seen between the groups in motor function demonstrates that the groups were well balanced for motor status and confirms that any differences found in the other parameters were not as a result of varying degrees of recovery between the groups.

No correlation was found between pain and subluxation in this study, which supports the assertions of previous authors.^{7,9} However, as subjects were followed-up only for a 3-month period after stroke, development of pain due to chronic stretching of soft tissues in the longer term cannot be precluded.

No subject who scored a grade of ≥ 2 on the Motor Assessment Scale developed subluxation. This may provide useful information on which patients are likely to benefit from treatment and when treatment can be withdrawn without risk of subluxation.

Concerns that subjects would find the treatment uncomfortable or inconvenient were unfounded. All subjects reported that the sensation of the muscle contraction and resultant movement of the limb were encouraging. This was particularly true when sensory inattention was present.

The study size was relatively small; however, a treatment effect was demonstrated. This study did not consider measures of disability, concentrating instead on impairment measures. It would be of interest to investigate the functional benefit of the prevention of subluxation.

Because the beneficial effect seen over the treatment period was not maintained after withdrawal of treatment,

TABLE 3. Verbal Rating Scale of Pain

Assessment	Verbal Rating Scale of Pain									
	Control Group					Treatment Group				
	0	1	2	3	4	0	1	2	3	4
1	18	2	0	0	0	11	4	2	3	0
2	10	4	3	3	0	7	5	7	1	0
3	6	4	6	3	1	7	4	6	2	1

Frequency of each category of the scale for each assessment is shown.

further studies are necessary to investigate the use of electrical stimulation over a longer period. The results of this study suggest that such a study should recruit subjects scoring ≤ 2 on the Motor Assessment Scale and that attainment of this score would be a good indication of when treatment could be discontinued.

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